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THE Marquardt CORPORATION OGDEN, UTAH

Report 15084

(Title Unclassified)

RESULTS OF THE PHASE II LONG-TERM ENVIRONMENTAL STORAGE TEST PROGRAM FOR THE RJ43-MA-11 RAMJET ENGINE OCTOBER 1960 THROUGH OCTOBER 1963

Contract AF 33(657)-7770
Project 273
Model RJ43-MA-11

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DATE 24 October 1963 REPORT 15084

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Contract AF 33(657)-7770
Project 273
Model RJ43-MA-11

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FOREWORD

A long-term storage evaluation program was initiated during CY 1960 under Air Force Contract AF 33(600)-40636 to document the effects of tactical usage environment on the storage capability of the RJ43-MA-11 ramjet engine.

The long-term storage test program was divided into Phase I and Phase II categories for reporting purposes. Phase I tests documented the effects of tactical environment on the RJ43-MA-11 engine, combustion chamber, and spare fuel control unit when stored in their respective storage containers. Phase II tests documented the effects of tactical environment on the RJ43-MA-11 engine when stored in a state of flight readiness.

Phase I of the storage test program was completed in March 1963 and the test findings were published in Marquardt Report No. 15081, Results of the Phase I Long-Term Environmental Storage Test Program For The RJ43-MA-11 Ramjet Engine, October 1960 Through March 1963, (Reference 1).

This report presents the test findings of Phase II of the long-term storage program which was initiated in October 1960 and completed in October 1963.

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ILLUSTRATIONS (Continued)

I SUMMARY

A long-term storage evaluation program was initiated during CY 1960 under Air Force Contract AF 33(600)-40636 to document the effects of tactical site environment on the storage capability of the RJ43-MA-11 engine. The phase of testing reported herein covers the documentation of long-term storage effects on the RJ43-MA-11 engine when stored in a state of flight readiness.

Tests conducted consisted of subjecting the RJ43-MA-11 engine to accelerated storage under severe environmental conditions and long-term storage under actual tactical environment conditions. Effects of the environmental tests on engine performance and structural integrity were evaluated by a comparison of pre- and post-storage power control system calibration data, by an engine combustion performance test, and by complete disassembly and inspection of the test items for any signs of deterioration.

The accelerated storage test imposed such severe and unrealistic environmental conditions on two test engines that the function and structural integrity of the engines were impaired to the point that the test program was redirected with approval by the Air Force. The accelerated storage test was beneficial in that it pointed out areas in which design changes could be effected to provide a satisfactory level of corrosion resistance in the RJ43-MA-11 engine.

The redirected storage effort subjected a rebuilt test engine to long-term storage under actual tactical environment conditions. Confidence in the functional and structural capability of the engine was demonstrated following this phase of testing by a successful combustion performance test, excellent agreement between pre- and post-storage power control system calibration data, and no signs of structural deterioration.

The storage test program conducted indicates that RJ43-MA-11 engines stored under tactical environment conditions in the state of flight readiness have a long storage life and confidence can be placed in the operation of the engines when put into service subsequent to storage.

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II TEST OBJECTIVE

The prime objective of the long-term storage program was to determine the effect of tactical environment on the storage capability of the RJ43-MA-11 ramjet engine. Specifically, the test objectives were to determine (1) if the life of the engine is compatible with the ten-year design life objective, (2) if the two-year interval for conduct of functional confidence checks, established in the IM-99B logistics support plan, is compatible with the design of the power control system, and (3) what elements, if any, are likely to be troublesome in operational usage of the engine.

III DISCUSSION OF ORIGINAL TEST PROGRAM

A. Test Plan

The original test plan for the conduct of the RJ43-MA-11 long-term environmental storage test program is described in Marquardt Report 15036, Outline for the RJ43-MA-11 Ramjet Engine and Components Missile-Ready Environmental Storage Test Program (Reference 2). Briefly, Phase II of this plan involved storing two flight-worthy RJ43-MA-11 ramjet engines in accelerated and simulated ready-storage environments and evaluating the effect of the storage environment on the performance and structural integrity of the engines. The various tests designed to accomplish these objectives are listed below in chronological order and are discussed in detail later in this section of the report.

1. Engine prestorage operational test.
2. Accelerated environmental storage test.
3. Engine functional and structural evaluation.
4. Long-term environmental storage test.
5. Functional evaluation of one engine at periodic intervals during the long-term storage period.
6. Poststorage evaluation of engine performance and structural integrity.

B. Test Items

The test items utilized in the Phase II storage test program consisted of two flight-type RJ43-MA-11 engines. Both engines were of basic production engine configuration with extra test instrumentation added (Marquardt P/N X221800-705). The individual test items are further described below.

1. Engine Serial MA-E14901-1

The main engine structure and the fuel control unit, Serial 013, installed in the engine were former test units which were refurbished for the storage test program. The engine combustion chamber was new hardware.

2. Engine Serial MA-E10011-1

The main engine structure and the combustion chamber were new hardware. The fuel control unit, Serial 005, installed in the engine was a former test unit which was refurbished for the storage test program.

Each engine was protected during the environmental tests by pull-off fabric covers, supplied by The Boeing Company, which fit tightly over the engine diffuser inlet and combustion chamber nozzle exit as shown and identified in Figure 1. This particular design of combustion chamber nozzle exit cover does not provide an adequate atmospheric seal because a passage way remains open from the atmosphere to the engine interior by way of the perforations in the nozzle shroud. The engine pneumatic exhaust tube should also have been covered with a Boeing-supplied plug. The plug did not fit the exhaust tube, however, and tape was utilized instead. Turbine exhaust and fuel overboard drain openings were not covered as is the case during engine ready-storage conditions.

C. Engine Prestorage Operational Test

1. General

Prior to the initiation of the environmental storage tests, each test engine was subjected to a comprehensive operational test to determine its compliance with the applicable specification governing the performance requirements of the test item. Data obtained during this test were to provide the criteria for checking satisfactory engine performance after the environmental storage tests.

2. Test Procedures

The operational test conducted on each test engine consisted of the standard MIL-Acceptance test conducted on all RJ43-MA-11 ramjet engines. The test includes (1) a preburn calibration test of the engine power control system, (2) a series of combustion tests to evaluate power scheduling and aerothermodynamic performance of the engine at various simulated flight conditions, and (3) a postburn recheck of the engine power control system.

The operational tests were conducted at the Air Force-Marquardt Jet Laboratory-Ogden (AF-MJL-0) during October and November 1960. The tests were conducted in accordance with Revision H of Marquardt Test Specification 0191, Acceptance Test Specification for the RJ43-MA-11 Ramjet Engine, (Reference 3).

3. Test Results

Results of the combustion and calibration tests conducted on engines Serial MA-E14901-1 and MA-E10011-1 met all requirements of Reference 3, Revision H. The final prestorage calibration data for each engine are presented in Figures 2 through 7 and Tables II and III.

D. Accelerated Environmental Storage Test

1. General

Accelerated environmental storage techniques were utilized to assist in the evaluation of the engine ten-year design life and to evaluate the engine structural capability under severe environmental conditions.

2. Test Procedures

The accelerated storage test was performed as outlined in TMC Report 15039, Environmental Testing of Three Selected RJ43-MA-11 Ramjet Engines and One Fuel Control Unit, (Reference 4). A description of the test procedure follows.

The test items for both Phase I and Phase II storage tests were placed together in a test chamber, Figure 1,equal to that described in Military Specification MIL-E-5272C (ASG), Environmental Testing, Aeronautical and Associated, General Specification for (Reference 5). The test chamber was vented to the atmosphere to prevent the buildup of pressure. Prior to the start of the test, the chamber temperature was between 68°F and 100°F with uncontrolled humidity.

Each test cycle consisted of three distinct periods. During the first period of four hours the temperature was to be raised to 160°F. This temperature was to be maintained during the second four-hour period. During the third period, lasting 16 hours, the temperature in the chamber was to be gradually reduced to between 68 and 100°F. The relative humidity was to be maintained at 95 $\pm$ 5 percent throughout the cycle. Steam or distilled water having a pH value between 6.5 and 7.5 at 77°F was to be used to obtain the desired humidity. The cycle described was to be repeated a total of ten times.

At the conclusion of the last cycle described above, the temperature in the test chamber was to be gradually lowered to -65°F in a three-hour period and maintained at -65°F during the next four-hour period. The temperature was to be gradually raised to standard conditions during the final three-hour period. The relative humidity was to be maintained at 15 percent or less during this cycle.

The accelerated storage test was conducted at the facilities of Utah Research and Development Company, Inc., in Salt Lake City, Utah, during November and December 1960. Test chamber temperature was raised by the use of a steam generator and lowered by injection of carbon dioxide during the high temperature-high humidity cycles. The chamber temperature was lowered by injection of carbon dioxide and raised by dry air from a gas blower during the low temperature-low humidity cycle. Air circulation was provided within the test chamber by two fans.

3. Test Results

The accelerated environmental test was conducted as outlined in the test procedure with two deviations. During the second high temperature cycle the temperature was erroneously maintained 20°F lower than required. During the low temperature cycle, the programmed rate of temperature decrease was not sufficient to reach the desired temperature level in the time specified. Actual test times and temperatures attained during each test cycle are shown

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in Table I. Relative humidity was maintained at 100 percent during the high temperature cycles and at 15 percent or lower during the low temperature cycle. The pH value of the water used for generating steam during the high temperature cycles was 6.8 at 77°F.

At the conclusion of the accelerated environment test localized areas of corrosion were noted on the exterior surfaces of the engines.

E. Engine Functional and Structural Evaluation

1. General

Functional and structural evaluations were conducted on the test items to determine what effect the severe temperature-humidity environment of the accelerated storage test had on engine performance and structural integrity.

2. Test Procedures

The functional evaluation consisted of repeating the postburn calibration portion of the prestorage operational test in accordance with Reference 3, Revision H. The structural evaluation consisted of a superficial inspection of each test item for evidence of corrosion or similar form of deterioration. These evaluations were conducted at AF-MJL-O during January 1961.

3. Test Results

Superficial examination of the test items showed that the severe temperature and humidity environment experienced during the accelerated storage test had caused extensive corrosion throughout the engine structure. Puddles of water were found inside the engine innerbody and between the diffuser skins several days after the engines had been removed from the accelerated storage test chamber. Corrosion was particularly severe in these areas and was generally found wherever dissimilar metals were in contact. The widespread corrosion and the degree to which the corrosion had progressed suggested that a more detailed inspection than originally planned would be required following the functional test.

The functional test of the engine Serial MA-E10011-1 power control system revealed several areas of discrepant operation. Figure 2 shows a lean shift in the minimum power fuel schedule which caused fuel flow at two of the seven check points to fall below the calibration lean tolerance, though they did remain within the operational tolerance band. The increased minimum and maximum power fuel schedules also shifted lean, because of the minimum power shift, but did not exceed the calibration tolerance limits. The Mach senser would not modulate within the tolerance limits at the high-altitude cruise setting as illustrated by the scattered data in Figure 3. The

Mach senser did function within required limits at the mid-altitude cruise setting, but exhibited considerable hysteresis during modulation and had shifted to a lower output pressure ratio on the lean-limit stop as shown in Figure 3. The shock position control calibration data exhibited excellent agreement with the prestorage data as shown by Figure 4. The dynamic response of fuel flow to a step in the fuel scheduling parameter, $Pt_{1.4}$, failed to meet Reference requirements for overshoot and final value time as shown in Table II.

The functional test of the power control system in engine Serial MA-E14901-1 showed excellent overall agreement with the prestorage calibration data. A comparison of the prestorage and poststorage data for the overall power control system, Mach senser, and shock position control are shown in Figures 5 through 7. Dynamic response data are presented in Table III.

The unfavorable results of the functional and structural evaluation caused a suspension of further storage test effort while the possibility of redirecting the test program was investigated. This activity is discussed in Section IV.

TABLE I
SUMMARY OF TEMPERATURE-HUMIDITY TEST CYCLE RESULTS
DURING RJ43-MA-11 PHASE II ACCELERATED STORAGE TEST

HIGH TEMPERATURE-HIGH HUMIDITY TEST REQUIREMENT

TEST CYCLE	PERIOD 1		PERIOD 2		PERIOD 3		RELATIVE HUMIDITY (PERCENT)
	TIME (HRS)	TEMPERATURE (°F)	TIME (HRS)	TEMPERATURE (°F)	TIME (HRS)	TEMPERATURE (°F)	
10	4	68/100 to 160 ± 5	4	160 ± 5	16	(160 to 68/100) ± 5	95 ± 5
TEST RESULTS							
1	4	90 to 160	4	160/165	16	160 to 90	100
2	4	90 to 160	4	140	16	140 to 73	100
3	4	68 to 160	4	160	16	160 to 68	100
4	4	80 to 160	4	160	16	160 to 90	100
5	4	90 to 150	4	160	16	150 to 90	100
6	4	95 to 160	4	150/155	16	162 to 90	100
7	4	90 to 160	4	160/165	16	160 to 93	100
8	4	90 to 160	4	160/165	16	160 to 90	100
9	4	83 to 160	4	160/165	16	160 to 83	100
10	4	90 to 160	4	160/165	16	160 to 90	100

LOW TEMPERATURE-LOW HUMIDITY TEST REQUIREMENT

TEST CYCLE	PERIOD 1		PERIOD 2		PERIOD 3		RELATIVE HUMIDITY (PERCENT)
	TIME (HRS)	TEMPERATURE (°F)	TIME (HRS)	TEMPERATURE (°F)	TIME (HRS)	TEMPERATURE (°F)	
1	3	(68/100 to -65) ± 5	4	(-65) ± 5	3	(-65 to AMB) ± 5	$\lesssim$ 15
TEST RESULTS							
1	3.5	60 to -60	3.75	-60/-65	3	-65 to 60	< 15

NOTE: Temperatures taken from temperature recorder charts.

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TABLE II

RJ43-MA-11 RAMJET ENGINE SERIAL MA-E10011-1
DYNAMIC RESPONSE DATA SHEET

Item			Required Dynamic Response Test Check Points	Pre-Storage	Post Storage	Allowed
$P_{26.5}$ DYNAMIC RESPONSE TEST	$P_{26.5}$ STEP INPUT	A	Overshoot	1%	4%	≤ 12%
		B	Rise Time — Time to 50% before overshoot	0.05 sec.	0.05 sec.	≤ 0.15 sec.
		C	Final Value Time — time required to reach and remain within ± 10% of final value	0.11 sec.	0.11 sec.	≤ 0.50 sec.
	W_{f_t} RESPONSE	A	Dead Time	0.05 sec.	0.06 sec.	≤ 0.30 sec.
		B	Overshoot	0%	2%	≤ 15%
		C	50% Response Time before overshoot	0.10 sec.	0.11 sec.	≤ 0.50 sec.
		D	Final Value Time — time to reach and remain within ± 10% of final value	0.10 sec.	0.16 sec.	≤ .85 sec.
$P_{t_{1.4}}$ DYNAMIC RESPONSE TEST	$P_{t_{1.4}}$ STEP INPUT	A	Rise Time — time to 50% value before overshoot	0.08 sec.	0.08 sec.	≤ 0.15 sec.
		B	Final Value Time — time to reach and remain within ± 10% of final value	0.25 sec.	0.24 sec.	≤ 0.40 sec.
	W_{f_t} RESPONSE	A	Dead Time	0.07 sec.	0.08 sec.	≤ 0.20 sec.
		B	Overshoot	14%	28%	≤ 15%
		C	50% Response Time before overshoot	0.23 sec.	0.21 sec.	≤ 0.25 sec.
		D	90% Response Time before overshoot	0.34 sec.	0.30 sec.	≤ 0.40 sec.
		E	Final Value Time — time required to reach and remain within ± 10% of final value	0.34 sec.	0.73 sec.	≤ 0.65 sec.
P_{t_6} DYNAMIC RESPONSE TEST	P_{t_6} STEP INPUT	A	Overshoot	2%	2%	≤ 12%
		B	50% Response Time before overshoot	0.02 sec.	0.03 sec.	≤ 0.20 sec.
		C	Final Value Time — time to reach and remain within ± 10% of final value	0.07 sec.	0.09 sec.	≤ 0.40 sec.
	W_{f_t} RESPONSE	A	Dead Time	0.12 sec.	0.17 sec.	≤ 0.30 sec.
		B	Overshoot	0%	5%	≤ 15%
		C	50% Response Time before overshoot	0.18 sec.	0.21 sec.	≤ 0.50 sec.
		D	Final Value Time — time required to reach and remain within ± 10% of final value	0.38 sec.	0.31 sec.	≤ 0.85 sec.

NOTE: All times are measured from the zero time point of the step input.

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TABLE III

RJ43-MA-11 RAMJET ENGINE SERIAL MA-E14901-1 DYNAMIC RESPONSE DATA SHEET

Item			Required Dynamic Response Test Check Points	Pre-Storage	Post Storage	Allowed
$P_{26.5}$ DYNAMIC RESPONSE TEST	$P_{26.5}$ STEP INPUT	A	Overshoot	2%	0%	≤ 12%
		B	Rise Time — Time to 50% before overshoot	0.04 sec.	0.05 sec.	≤ 0.15 sec.
		C	Final Value Time — time required to reach and remain within ± 10% of final value	0.11 sec.	0.10 sec.	≤ 0.50 sec.
	W_{f_t} RESPONSE	A	Dead Time	0.04 sec.	0.04 sec.	≤ 0.30 sec.
		B	Overshoot	0%	8%	≤ 15%
		C	50% Response Time before overshoot	0.11 sec.	0.12 sec.	≤ 0.50 sec.
		D	Final Value Time — time to reach and remain within ± 10% of final value	0.15 sec.	0.18 sec.	≤ .85 sec.
$P_{t_{1.4}}$ DYNAMIC RESPONSE TEST	$P_{t_{1.4}}$ STEP INPUT	A	Rise Time — time to 50% value before overshoot	0.06 sec.	0.08 sec.	≤ 0.15 sec.
		B	Final Value Time — time to reach and remain within ± 10% of final value	0.23 sec.	0.24 sec.	≤ 0.40 sec.
	W_{f_t} RESPONSE	A	Dead Time	0.06 sec.	0.06 sec.	≤ 0.20 sec.
		B	Overshoot	8%	7%	≤ 15%
		C	50% Response Time before overshoot	0.18 sec.	0.19 sec.	≤ 0.25 sec.
		D	90% Response Time before overshoot	0.32 sec.	0.30 sec.	≤ 0.40 sec.
		E	Final Value Time — time required to reach and remain within ± 10% of final value	0.32 sec.	0.30 sec.	≤ 0.65 sec.
P_{t_6} DYNAMIC RESPONSE TEST	P_{t_6} STEP INPUT	A	Overshoot	3%	0%	≤ 12%
		B	50% Response Time before overshoot	0.03 sec.	0.03 sec.	≤ 0.20 sec.
		C	Final Value Time — time to reach and remain within ± 10% of final value	0.08 sec.	0.08 sec.	≤ 0.40 sec.
	W_{f_t} RESPONSE	A	Dead Time	0.11 sec.	0.13 sec.	≤ 0.30 sec.
		B	Overshoot	0%	0%	≤ 15%
		C	50% Response Time before overshoot	0.16 sec.	0.20 sec.	≤ 0.50 sec.
		D	Final Value Time — time required to reach and remain within ± 10% of final value	0.35 sec.	0.35 sec.	≤ 0.85 sec.

NOTE: All times are measured from the zero time point of the step input.

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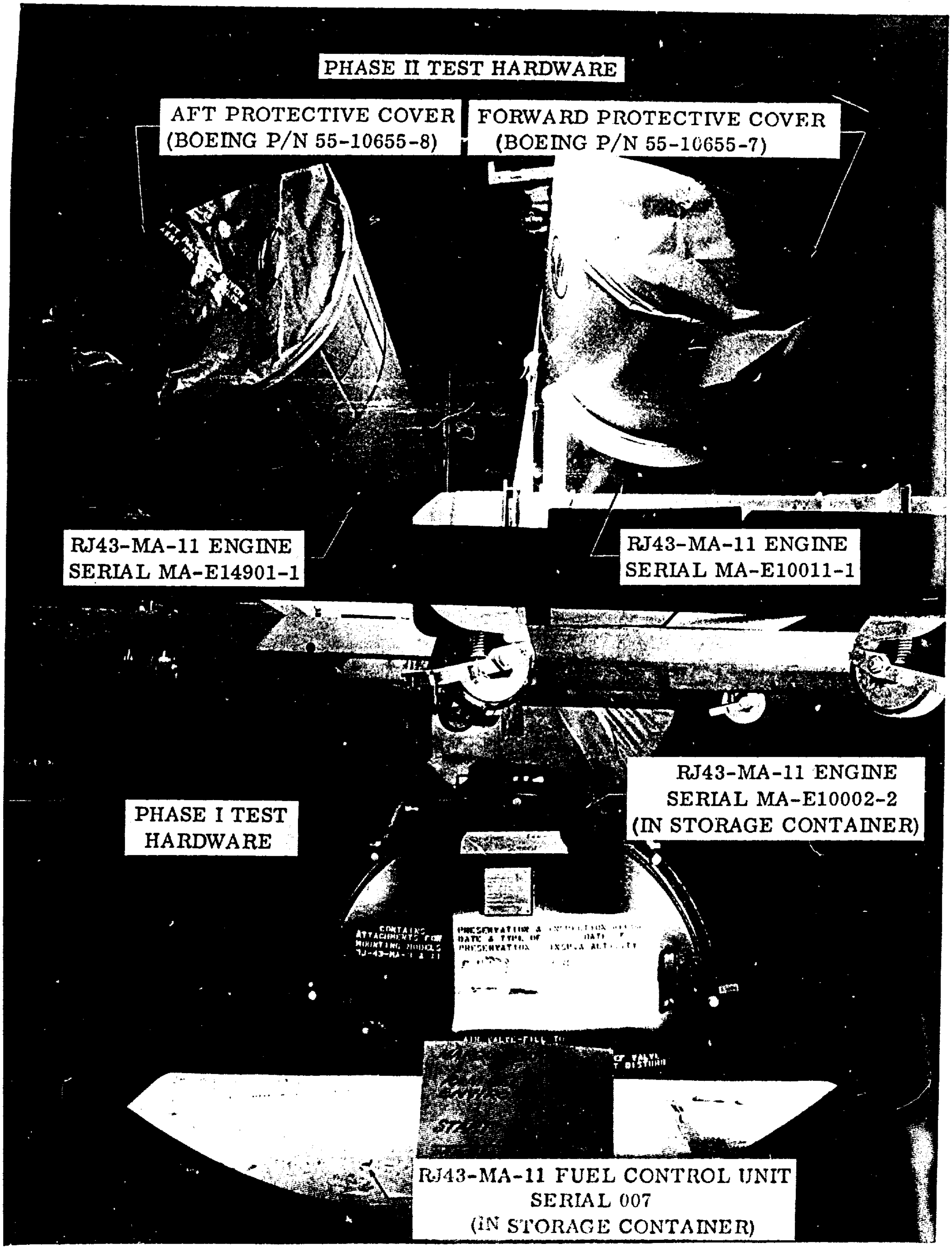

FIGURE 1 - RJ43-MA-11 Test Hardware Installed in Environmental Test Chamber at the Start of the Accelerated Storage Test Phase of the RJ43-MA-11 Long-Term Storage Test.

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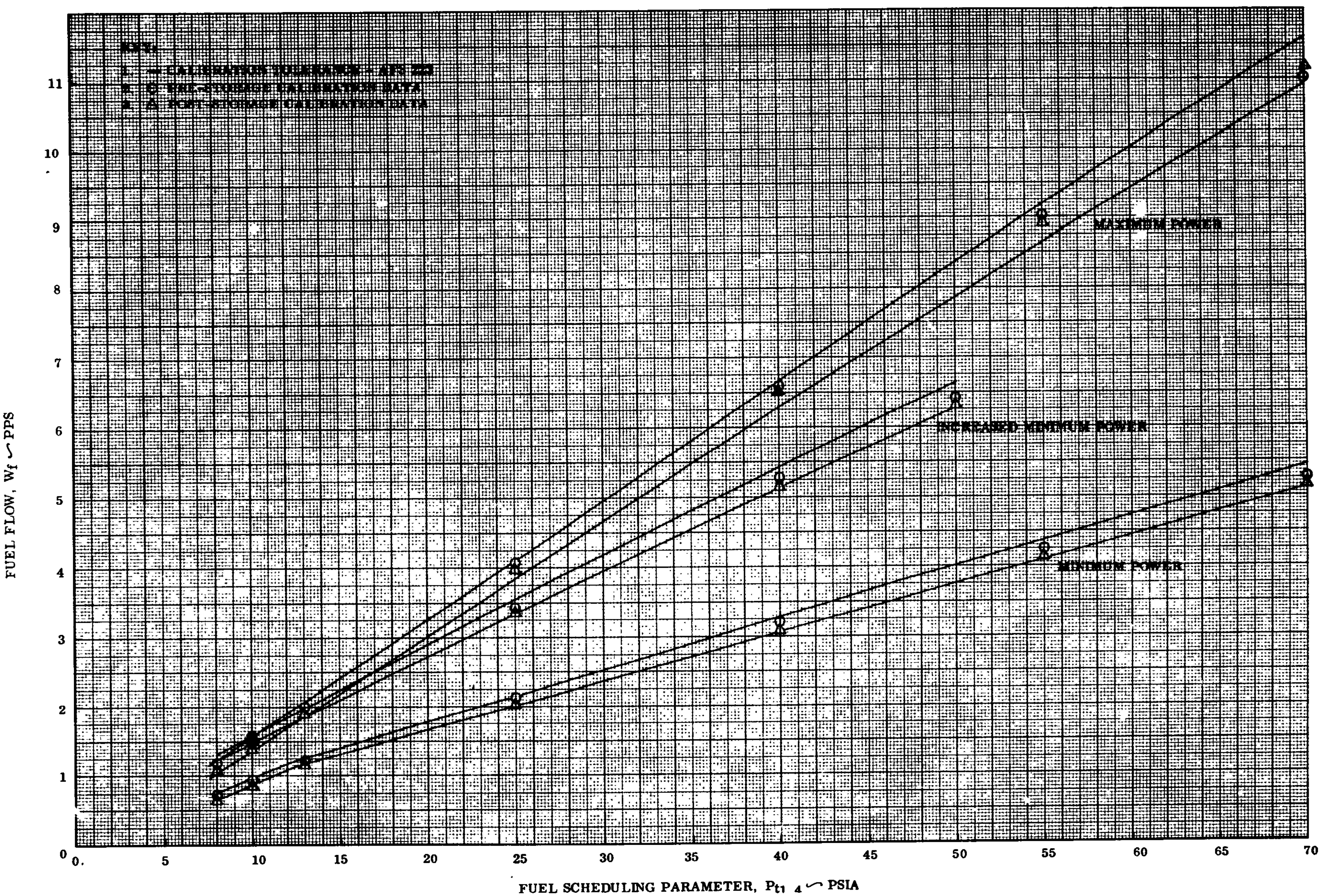

FIGURE 2 - RJ43-MA-11 Ramjet Engine Serial MA-E10011-1 Overall Power Control System Calibration Data Before and After the RJ43-MA-11 Phase II Accelerated Storage Test.

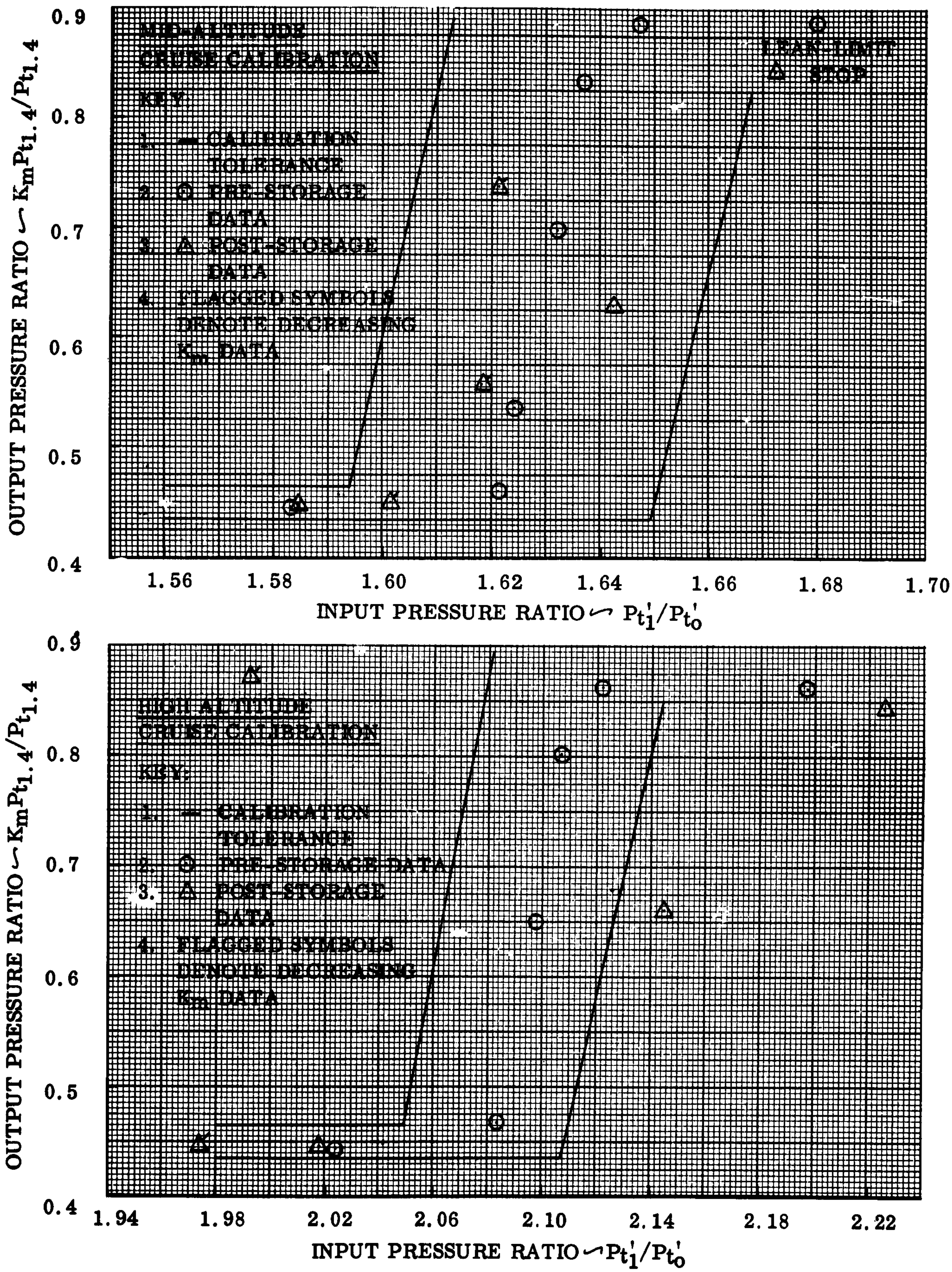

FIGURE 3 - RJ43-MA-11 Ramjet Engine Serial MA-E10011-1 Mach Senser Control Calibration Data Before and After the RJ43-MA-11 Phase II Accelerated Storage Test.

KEY:

1. — CALIBRATION TOLERANCE
2. ⊙ PRE-STORAGE DATA
3. △ POST-STORAGE DATA
4. FLAGGED SYMBOLS DENOTE DECREASING K_p DATA

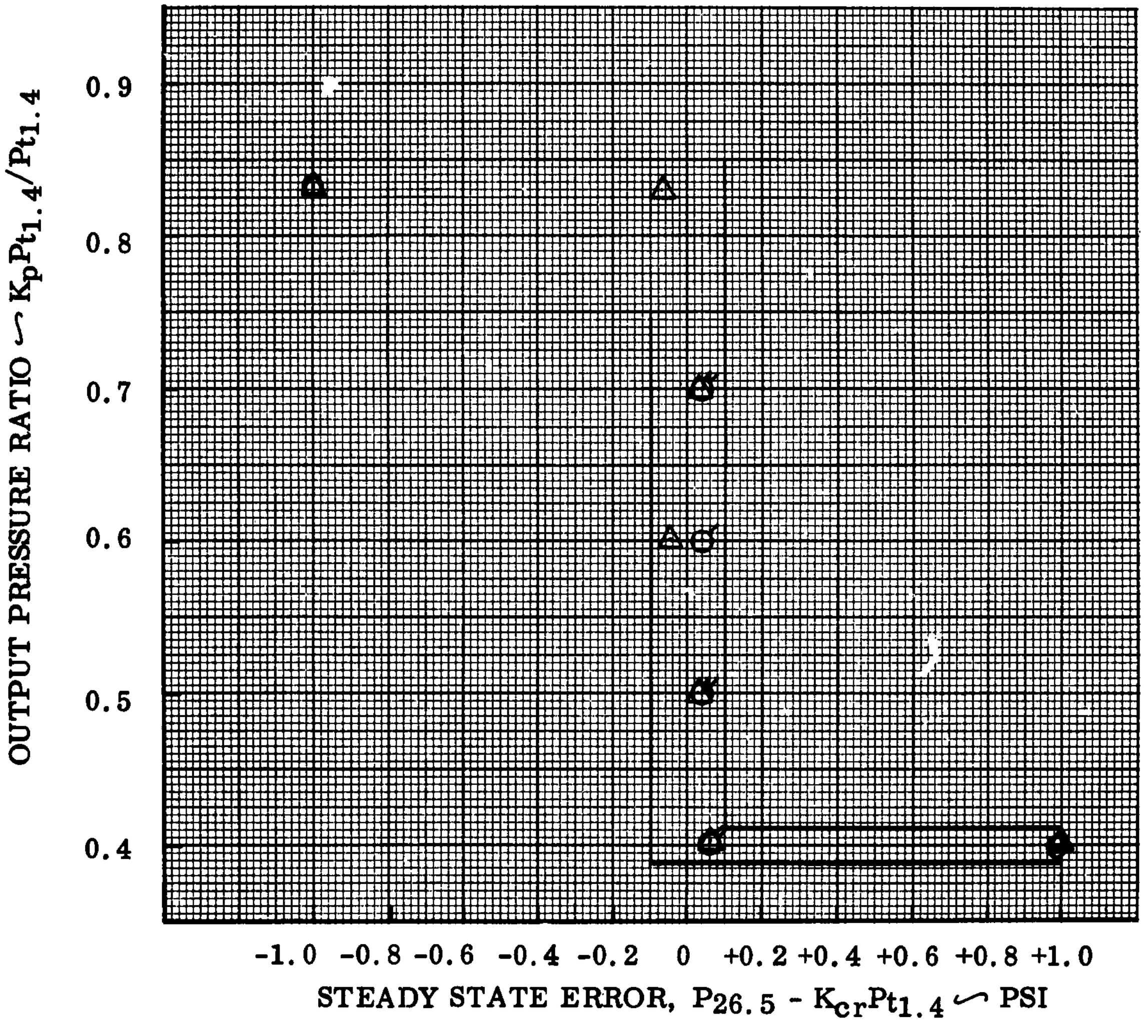

FIGURE 4 - RJ43-MA-11 Ramjet Engine Serial MA-E10011-1 Shock Position Control Calibration Data Before and After the RJ43-MA-11 Phase II Accelerated Storage Test.

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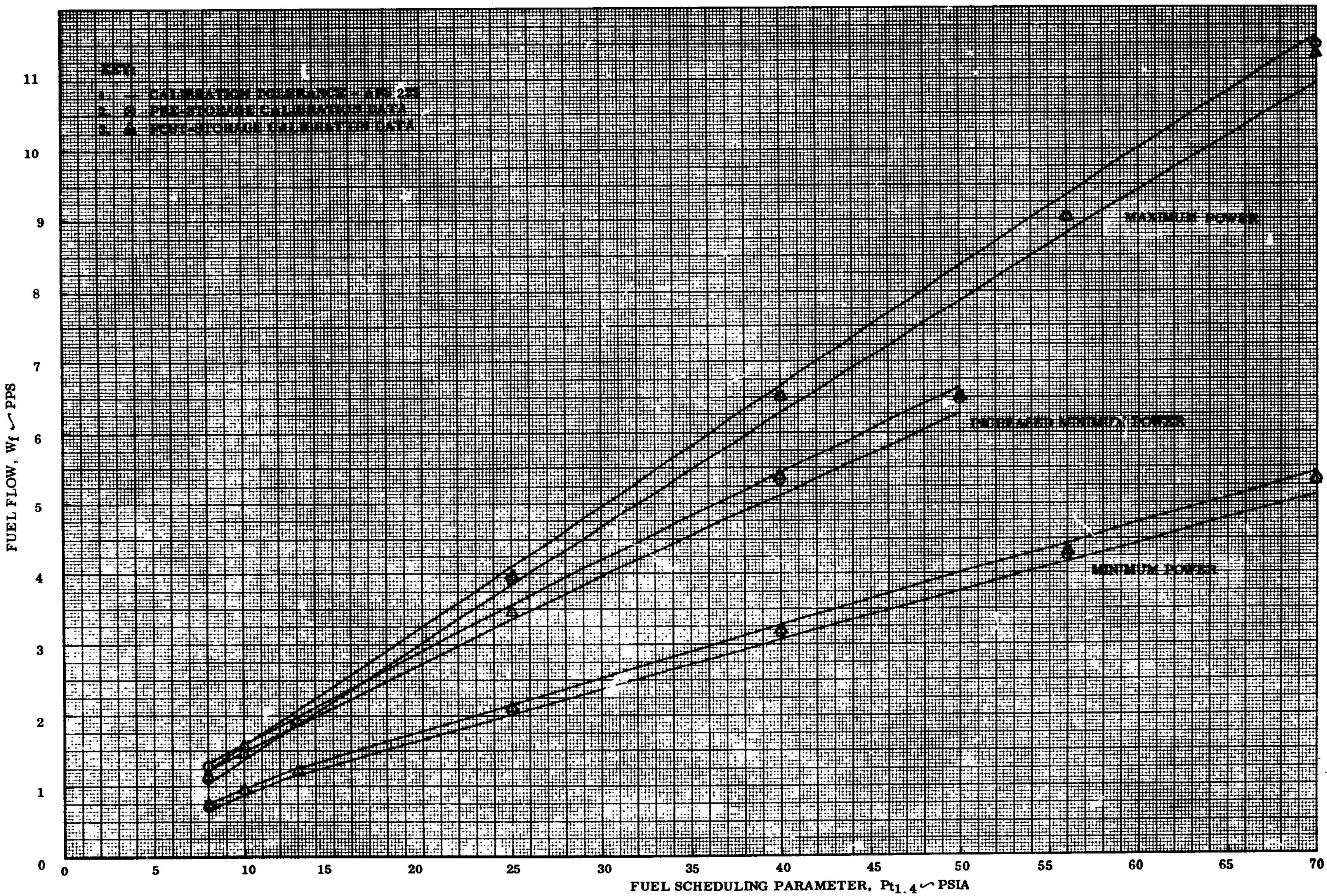

FIGURE 5 - RJ43-MA-11 Ramjet Engine Serial MA-E14901-1 Overall Power Control System Calibration Data Before and After the RJ43-MA-11 Phase II Accelerated Storage Test.

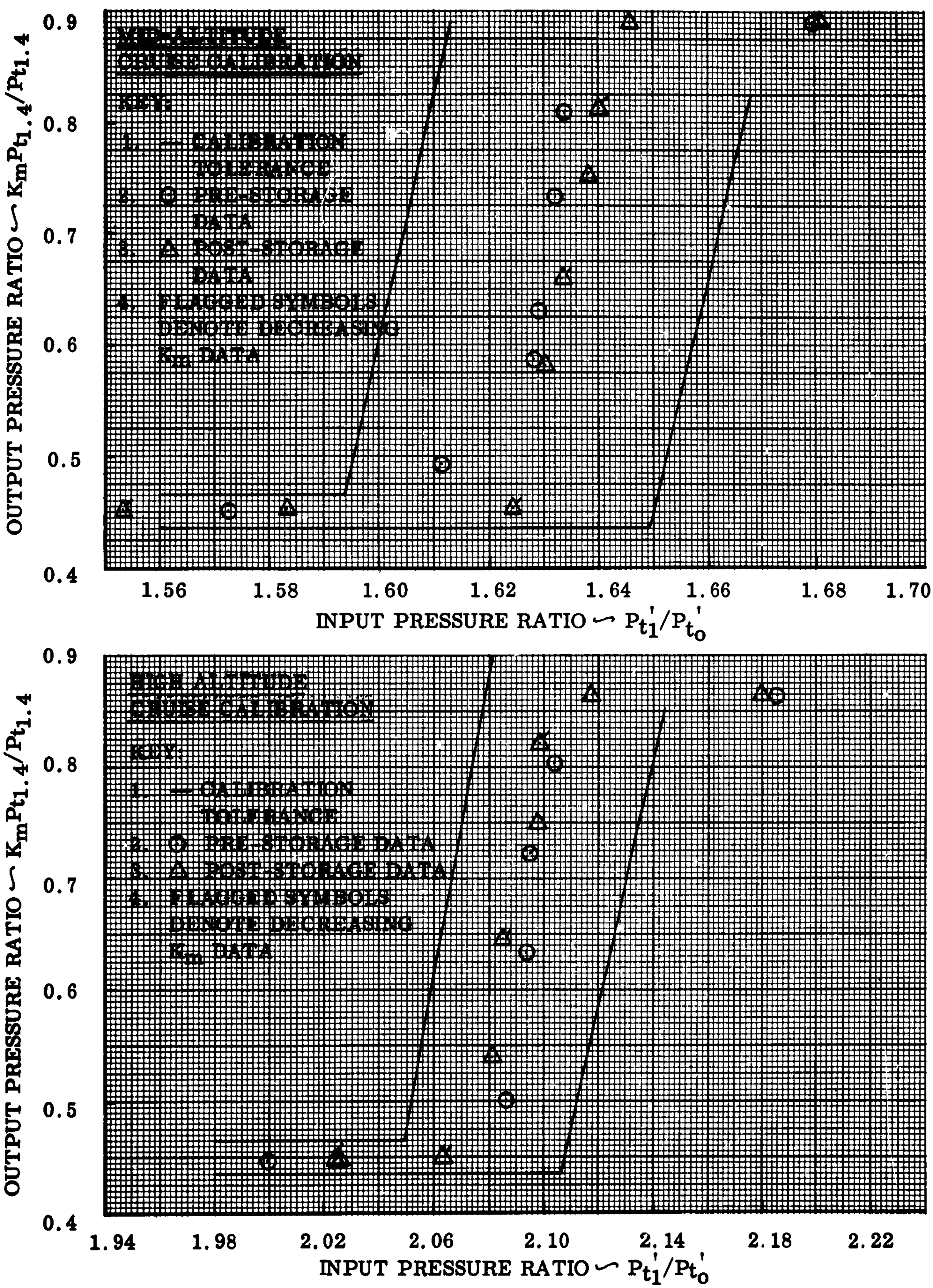

FIGURE 6 - RJ43-MA-11 Ramjet Engine Serial MA-E14901-1 Mach Senser Control Calibration Data Before and After the RJ43-MA-11 Phase II Accelerated Storage Test.

KEY:

1. — CALIBRATION TOLERANCE
2. ⊙ PRE-STORAGE DATA
3. △ POST-STORAGE DATA
4. FLAGGED SYMBOLS DENOTE DECREASING K_p DATA

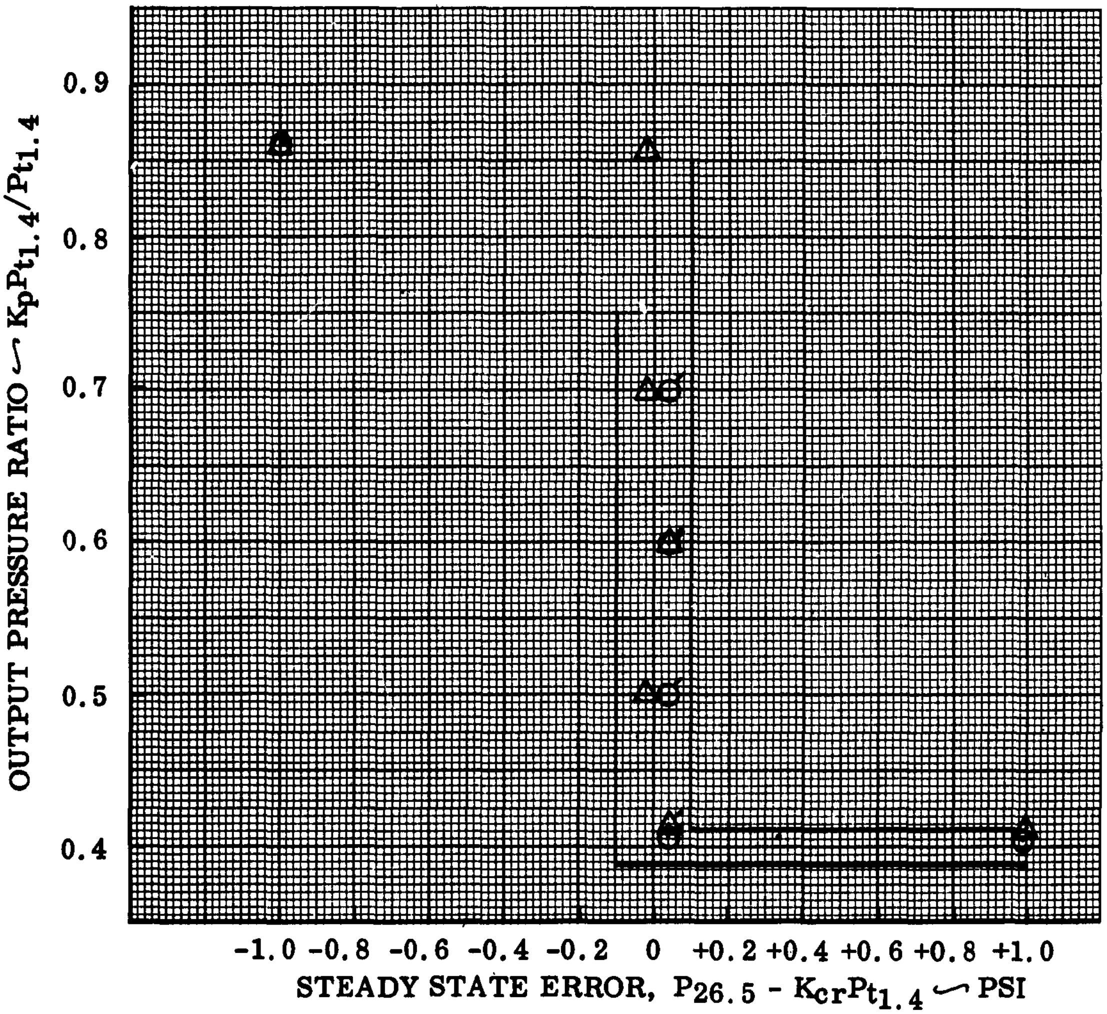

FIGURE 7 - RJ43-MA-11 Ramjet Engine Serial MA-E14901-1 Shock Position Control Calibration Data Before and After the RJ43-MA-11 Phase II Accelerated Storage Test.

IV TEST PROGRAM REDIRECTION

A. General

The functional and limited structural evaluations conducted on engines Serial MA-E10011-1 and MA-E14901-1 following the accelerated environmental storage test left no doubt about the need for redirecting the long-term storage test program. The test program to this point had been beneficial since valuable structural and functional information pertaining to the environmental storage capability of the RJ43-MA-11 engine had been provided. But little or no information of value could have been obtained by continuing on with the test program as outlined in Section III. It was therefore proposed to redirect the effort required to complete the storage test program.

Redirection of the program allowed a complete and thorough analysis to be made of the structural damage sustained by the engines during the accelerated storage test. Information derived from this analysis showed what design changes were needed to provide the RJ43-MA-11 engine with a satisfactory level of corrosion resistance. Design changes derived from the storage test were immediately incorporated into engines yet to be delivered under the production contract. The structural evaluation results and the design changes incorporated are discussed later in this section of the report.

The redirected test program plan adopted and approved by the Air Force provided a more realistic evaluation of the RJ43-MA-11 engine storage capability by subjecting the engine only to the environmental conditions which it would encounter in tactical usage. The redirected storage program is discussed in Section V.

B. Structural Evaluation

Engine Serial MA-E10011-1 and its associated fuel control unit were completely disassembled and thoroughly inspected to determine in what areas design changes could be made to improve the level of corrosion resistance in the RJ43-MA-11 engine.

Corrosion in varying stages of severity was found throughout the engine structure. Corrosion was in an advanced stage in localized areas of the engine innerbody and between the diffuser skins where water had accumulated during the accelerated storage test. The engine outer skin and aerodynamic grid showed evidence of corrosion beneath the coat of paint. Corrosion was generally found wherever dissimilar metal was in contact with unprotected magnesium parts. Steel spirolox rings, retainer rings, and unpainted areas of the burner assembly and aft mount showed some rust. Pyrochrome paint on the burner assembly had a tendency to flake off.

The hydraulic systems of the fuel control unit were in good condition while the pneumatic systems, open to the accelerated storage environment, contained much corrosion. Bolts, plugs, and other threaded components were difficult to remove from the magnesium castings. Corrosion was generally found where dissimilar metals were in contact with magnesium. Steel details such as springs, bearings, push-rods, pistonsleeve assemblies, and adjustment mechanisms showed evidence of rust. The Mach senser diaphragm stuck to the Mach senser cap and the variable divider piston was difficult to move with finger pressure. Corrosion deposit buildup around the tips of the turbopump rotor blades prevented rotation of the turbopump impeller with finger pressure. Seal plates between the magnesium component slab assemblies showed slight corrosion.

Engine Serial MA-E14901-1 was partially disassembled and inspected. Its condition was the same as Serial MA-E10011-1 engine, but the corrosion generally was not as severe.

Figures 8 through 37 illustrate the extent and severity of corrosion found during the structural evaluation.

C. Design Changes

The severe extremes of temperature and humidity imposed on the test engines during the accelerated storage test were not only much more severe than would be encountered in actual tactical usage environment, but also allowed no corrective action to minimize corrosion as would be done during periodic maintenance checks under actual usage conditions. Previous temperature and humidity testing at less severe conditions during qualification and additional documentation tests had been conducted on the fuel control unit and components, and on various engine material samples. These previous tests resulted in only minor corrosion which was insufficient to cause functional impairment, and therefore corrective action was not considered to be necessary. The accelerated storage damage to the test engines could not be ignored, however, and many Class II design changes were incorporated into subsequent storage test hardware and into production engines.

A summary of the corrosion preventative changes incorporated into the RJ43-MA-11 fuel control unit and engine structure is listed below.

1. Fuel Control Unit

The machined fuel control unit magnesium castings were coated with "Marguard," a Marquardt-developed epoxy surface coating which has been approved by the Air Force. The coating is continuous and controllable to a thickness range of from 0.000050 to 0.000100 inch, thereby keeping within the tolerance limits of all bores, threaded holes, and ground surfaces of the fuel control unit castings.

2. Engine Structure

Marguard was added to all unpainted, HAE coated magnesium parts. Manufacturing processes were revised, where possible, to drill and countersink fastener holes in magnesium parts prior to HAE treatment. A coat of paint was added to all small parts such as washers, nut plates, clips, and clamps, etc. which contacted the magnesium parts.

A detailed listing of the design changes is presented in Table IV.

TABLE IV

CORROSION PREVENTATIVE DESIGN CHANGES INCORPORATED INTO LONG-TERM STORAGE HARDWARE

X221800 ENGINE RAMJET, RJ43-MA-11 (SERIAL MA-E10011-2)

PART NUMBER	DESCRIPTION	DESIGN CHANGE NOTE*
221910	Nose Cone Assembly	-
X221366	Nose Cone	(6)
222101	Key-Nose Cone	(2)
222116	Tip-Nose Cone	(8, 4, external surface only)
221302	Fwd. Cowling Assembly	-
221315	Lip	(4)
221082	Frame	(8, aft mating surface only)
F5031-1032	Nut Plate	(4)
MS20002C4	Washer	(4)
SP168A3A	Washer	(4)
224055	Bolt-Nose Cone	(4)
224025	Bolt-Lip Pylon	(4)(6)
X224101	Fwd. Innerbody Assembly	-
X224056	Fwd. Innerbody	(6)(8)
221664	Rail	(1)
AN960C8L	Washer	(4)
M14634HV-048	Dome Nut	(2)
TA716SS3FG	Clamp	(1)
MK3031-4	Anchor Nut	(1)
NAS1197-10	Washer	(4)
221740/41	Tube Assembly	(3)
221734/35	Tube Assembly	(3)
224096	Tube Assembly	(3)
221934/35	Valve	(3)
221885	Valve Tee	(3)
221401	Main Structure Assembly	-
221087	Ring Frame Assembly	(3, fwd. edge of -3, -5, -7 & outer surface of -7)
221257/58	Intercostal	(4)(5)
221338	Intercostal Doubler	(4)(5)
221294	Ring	(3, aft edge)
221444	Skin, Diffuser	(3, both edges)
221261	Splice	(5)
221088	Duct	(3)
221110	Connector	(1)(2)
221271/72	Plate-Intercostal	(5)
221313	Mount	(5)
221265/66	Clip-Intercostal	(3)(5)
221298	Aft Mount	(4)

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TABLE IV (Continued)

X221800 ENGINE RAMJET, RJ43-MA-11
(SERIAL MA-E10011-2)

PART NUMBER	DESCRIPTION	DESIGN CHANGE NOTE*
221709	Plate-Drain & Exhaust	(5)
221931	Bushing	(2)
221721	Shim	(2)
221255	Skin-Diffuser	(5)
221691	Outer Shell Frame	(3)
224045	Bracket	(1)(2)
221404	Fuel Upper Inlet	(8)
X221378	Elbow-Fuel Inlet	(8)
224058	Clip-Thrust Pin	(5)
221113	Duct-Fuel Overboard	(3)
222126	Pin-Thrust	(2)
221966	Washer	(4)
MF1031-3	Anchor Nut	(1)
MK2031-3	Anchor Nut	(1)
52LHA3022-02	Anchor Nut	(1)
TA207-2A3	Shim	(4)
TA207-1A3	Shim	(4)
AN960C10	Washer	(4)
AN960PD3L	Washer	(4)
TA105SS12	Angle Clip	(1)
AN960C10L	Washer	(4)
X221318	Aft Innerbody Assembly	-
X221345	Aft Innerbody	(4)(6)
X221369	Pylon-Main Upper	(4)(8)(6)
221112	Probe	(6)
221314	Pylon Auxiliary	(4)(6)
221281	Bracket	(1)(2)
221440	Bracket	(1)(2)
221441	Bracket	(1)(2)
221932	Clip	(1)(2)
221736	Clip	(1)(2)
221914	Bracket	(1)(2)
224060	Sump	(1)(2)
224093	Bracket	(1)(2)
AN960C10L	Washer	(4)
NAS1068C3M	Anchor Nut	(1)
NAS1068C4M	Anchor Nut	(1)
TA105SS-16	Clip	(1)
TA105SS-20	Clip	(1)
TA713TSS-16FG	Clamp	(1)
TA105SS-12	Clip	(1)

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TABLE IV (Continued)

X221800 ENGINE RAMJET, RJ43-MA-11
(SERIAL MA-E10011-2)

PART NUMBER	DESCRIPTION	DESIGN CHANGE NOTE*
AN960PD516L	Washer	(4)
AN960PD3L	Washer	(4)
AN960C416	Washer	(4)
AN960C10	Washer	(4)
TA716SS4FG	Clamp	(1)
TA716SS2FG	Clamp	(1)
TA716SS5FG	Clamp	(1)
TA713SST4FG	Clamp	(1)
X221429	Grid-Aerodynamic	(6)(8)
224087	Outer Burner Assembly	-
221371	Fitting	(2)(5)
224087-7	Skin	(2)(3)
224087-9	Skin	(2)(3)
224087-11	Skin	(2)(5)
X519000-MOD	Fuel Control Unit	-
519010	Heat Exchanger Assembly	-
519002	Housing	(6)
519020	Pressure Divider Assembly	-
519021	Housing	(6)
519050	Mach Senser-Shock Position Control Assembly	-
519035	Casting	(6)
519038	Cover-Actuator	(6)
519080	Crossover Slab Assembly	-
519079	Casting	(6)
519100	Flow Regulator Assembly	-
519084	Housing	(6)
519132	Elbow	(6)
519096	Cap	(6)
519411	Fuel Transfer Valve	-
519220	Housing	(6)
522300	Turbopump Assembly	-
519238	Pump Housing	(6)
519198	Elbow	(6)
519217	Turbine-Housing	(6)
519213	Manifold	(6)
519212	Stator-First Stage	(6)
519234	Retainer	(6)
522130	Exhaust Duct	(6)
519369	Coupling	(6)

TABLE IV (Continued)

*NOTES:

(1) Paint all faying surfaces with PT201 resin coating per Marquardt Process Specification (MPS) 505, Priming and Painting of Metal Surfaces (Reference 6), Appendix VI except: one coat only.

(2) Assemble faying surfaces wet with PT401 resin coating per MPS 505 Appendix IX.

(3) Paint all faying surfaces and adjacent edge or edges with PT201 resin coating per MPS 505 Appendix VI except: one coat only.

(4) Paint all surfaces with PT201 resin coating per MPS 505 Appendix VI except: one coat only.

(5) Install fasteners wet with PT401 resin coating per MPS 505 Appendix IX.

(6) Process with "Marguard" epoxy resin per MPS 505, Appendix XI.

(7) Threaded surfaces masked as required.

(8) Treat mating surfaces, register diameters, and sealing surfaces with silicone parting agent per MPS 505 Appendix XI.

(9) Fastener holes drilled and countersunk prior to HAE treatment where possible.

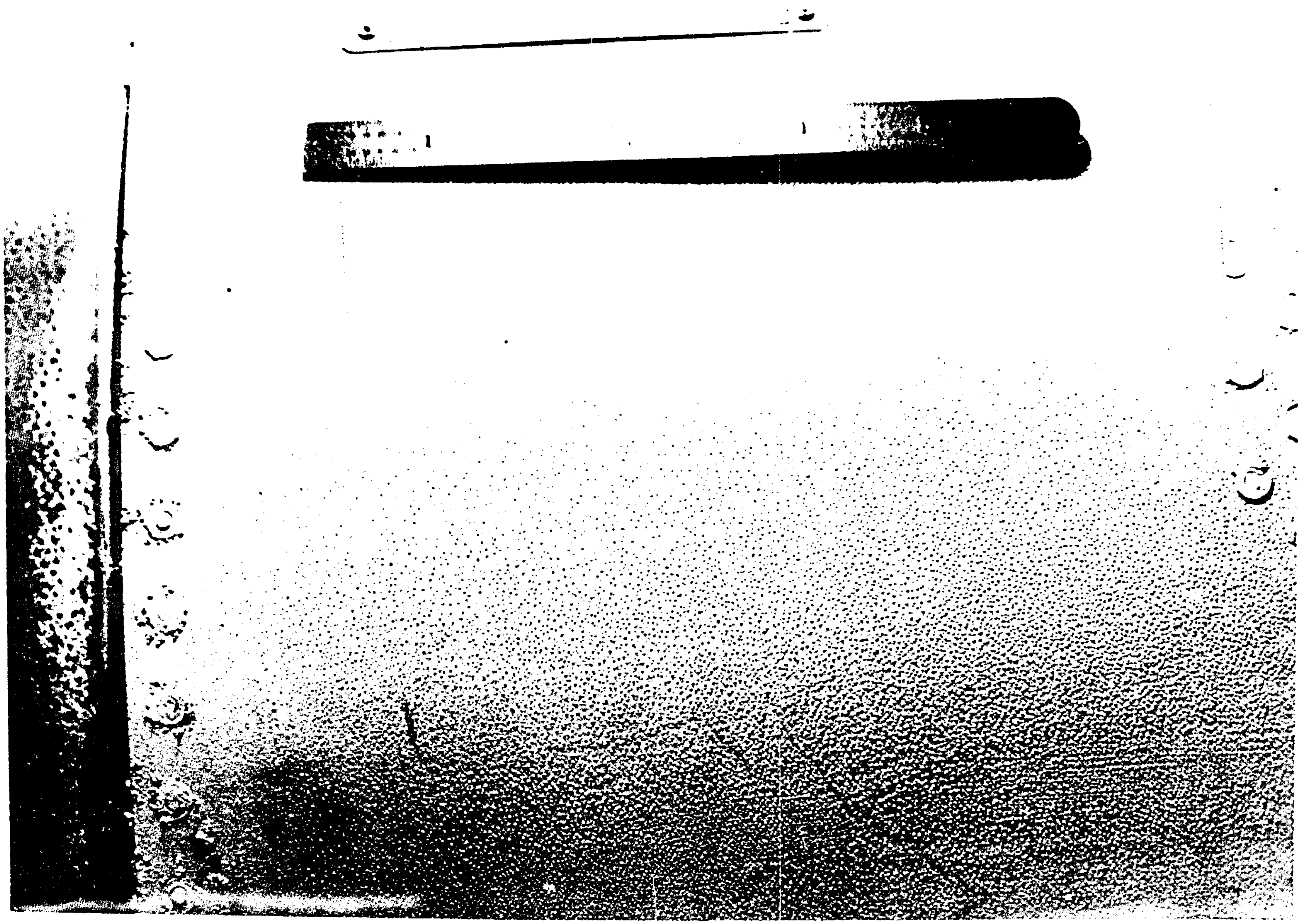

FIGURE 8 - Outer Skin from RJ43-MA-11 Engine Serial MA-E10011-1 Showing Corrosion Beneath Paint and Around Rivets Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

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FIGURE 9 - Outer Skin From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Advanced Stage Corrosion and Puddle Trace Where Water was Trapped Inside of Skin During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

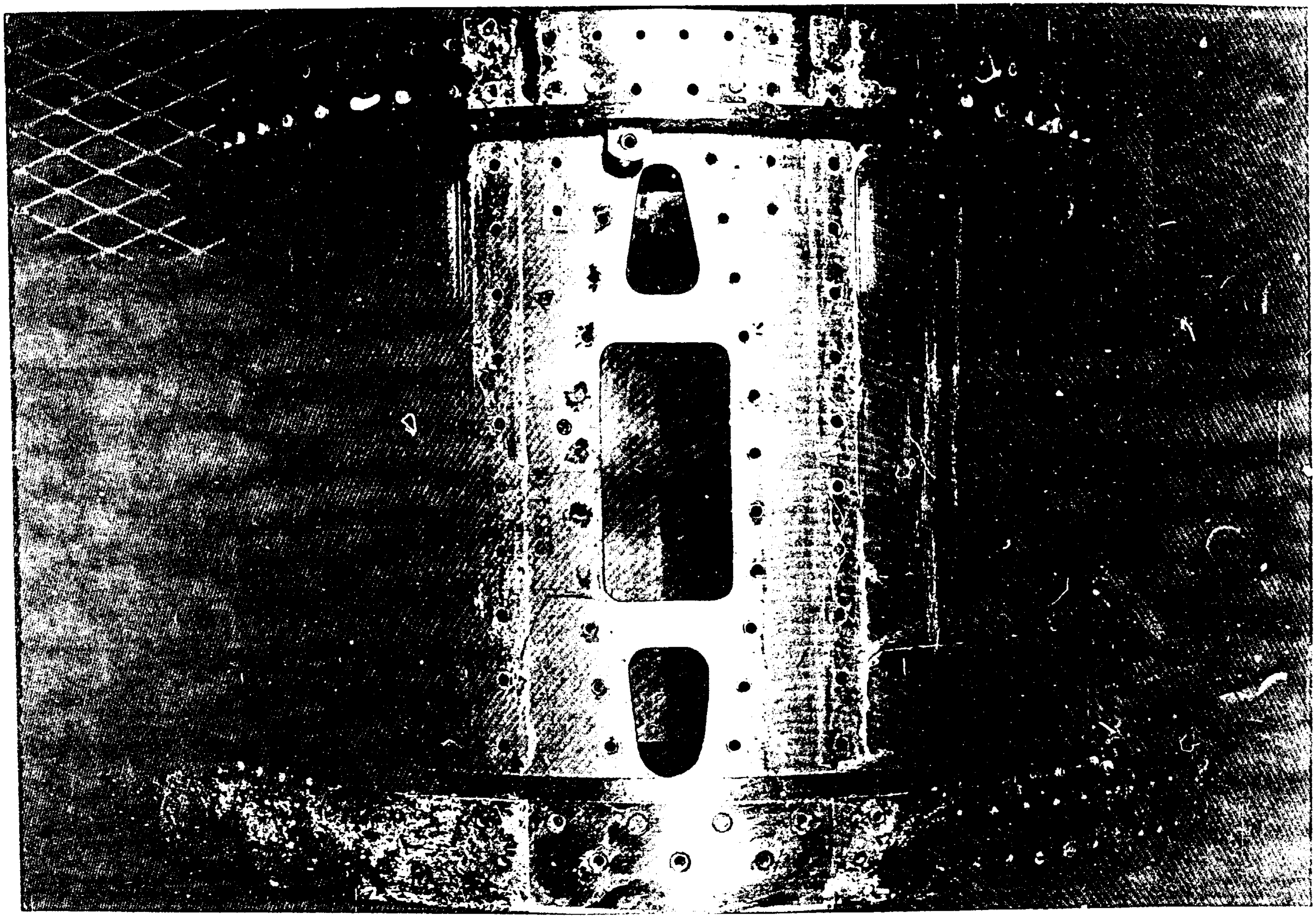

FIGURE 10 - Station 42.12 and 54.87 Ring Frames and Diffuser Skin from RJ43-MA-11 Engine Serial MA-E10011-1 Showing Deposits of Corrosion After Removal of Surrounding Magnesium Structure. No Damage to Titanium Details is Shown. Corrosion Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

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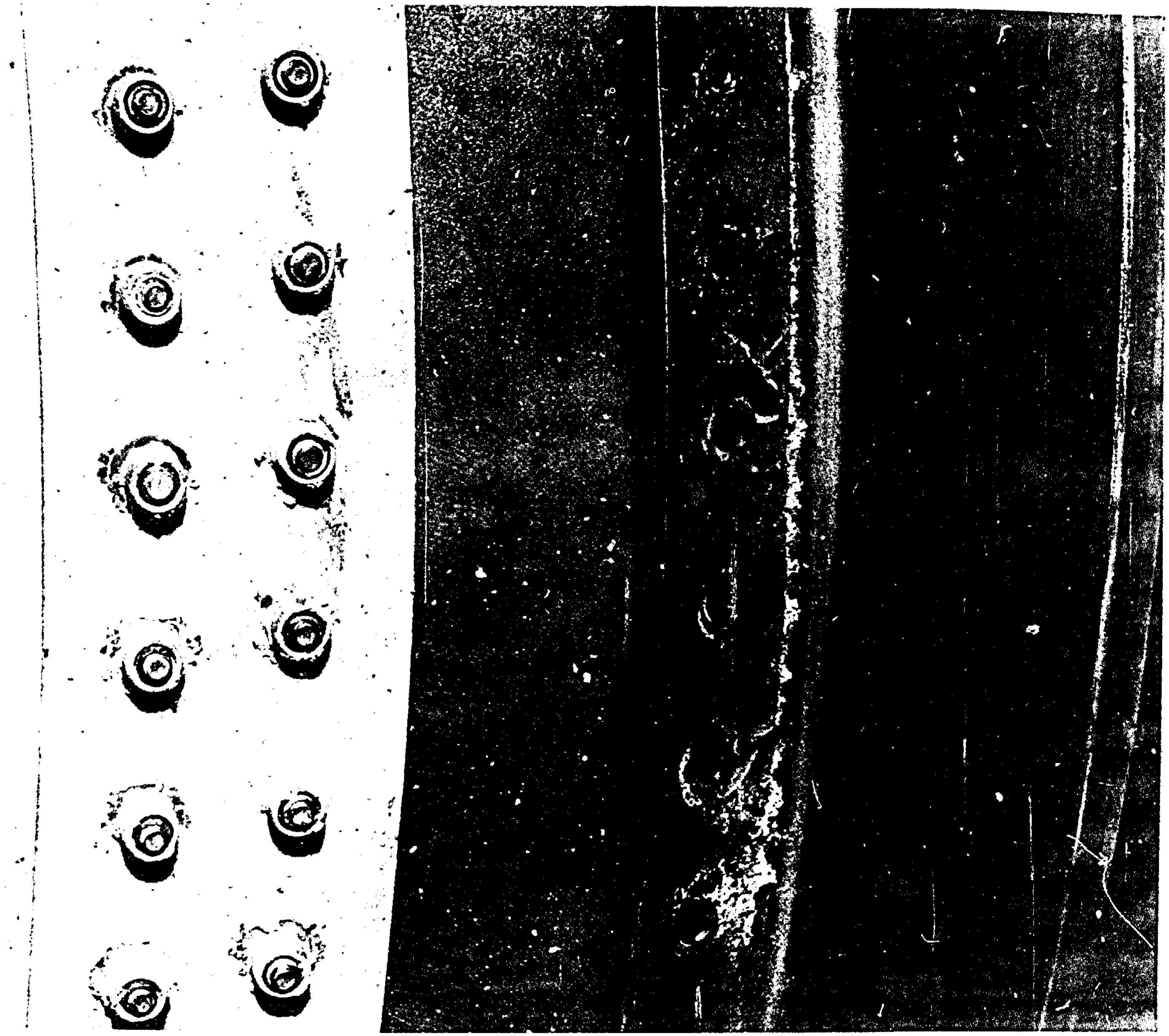

FIGURE 11 - Station 87.5 Ring Frame Assembly and Splice From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Corrosion Around Hi-Shear Blind Bolts and Outer Skin Attach Holes Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

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FIGURE 12 - Station 75.75 Ring Frame From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Corrosion, Due to Deburring and No Subsequent Protective Touch-up, Which Occurred Around Attach Holes During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

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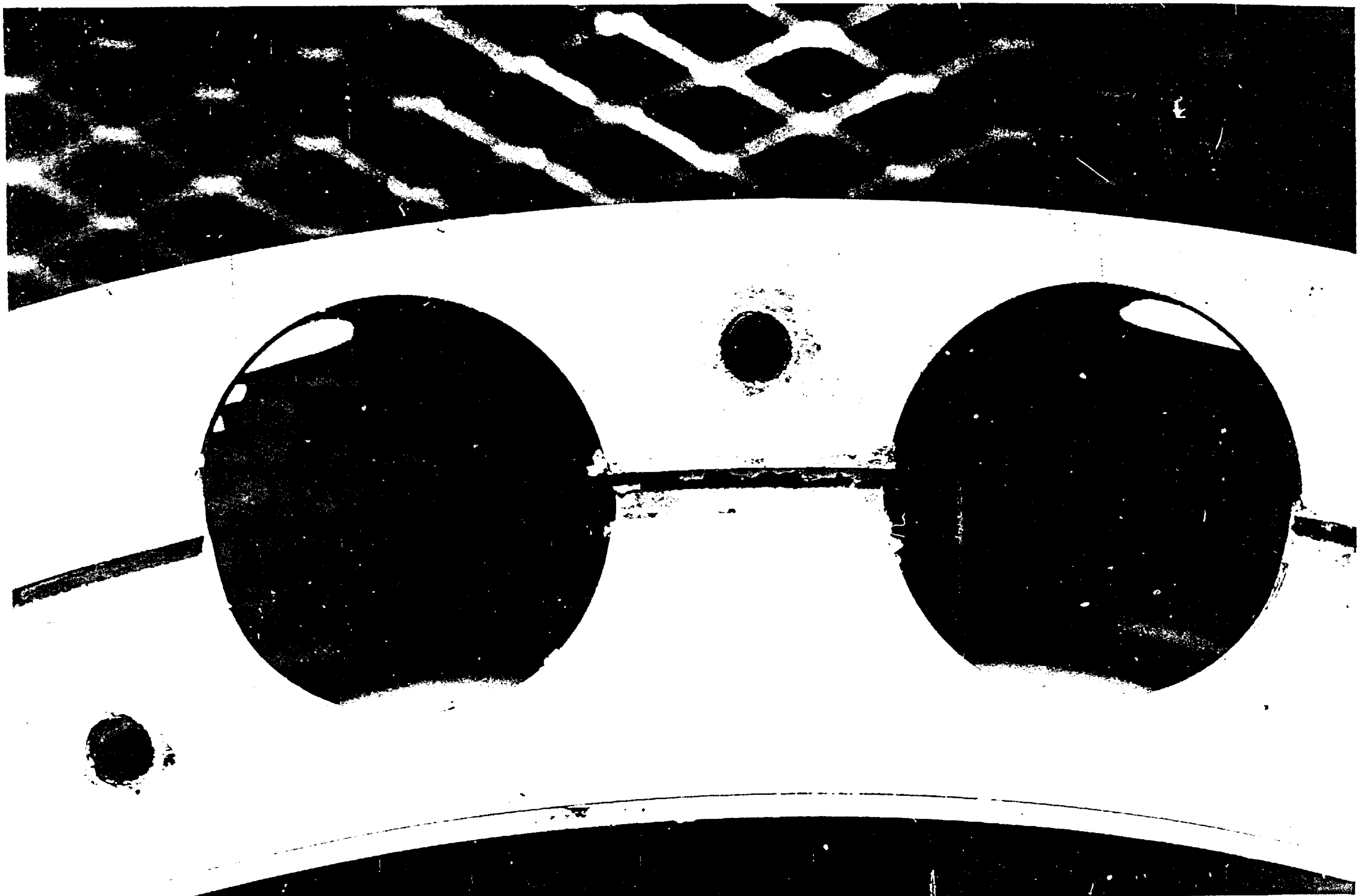

FIGURE 13 - Cowl Lip Assembly from RJ43-MA-11 Engine Serial MA-E10011-1 Showing Corrosion and Pitting in Index Groove Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

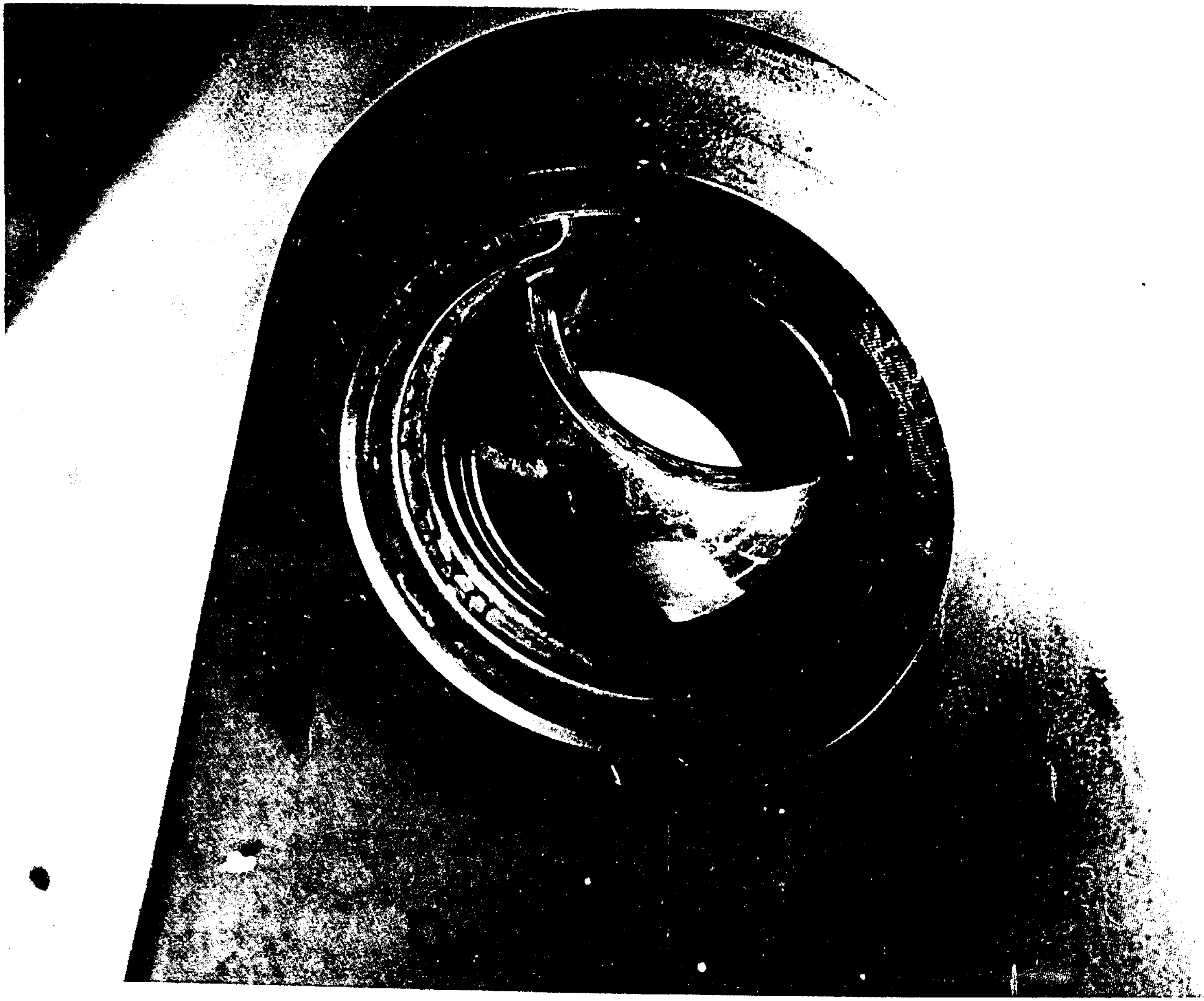

FIGURE 14 - Forward Engine Mount From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Rust on Bearing Retaining Ring Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

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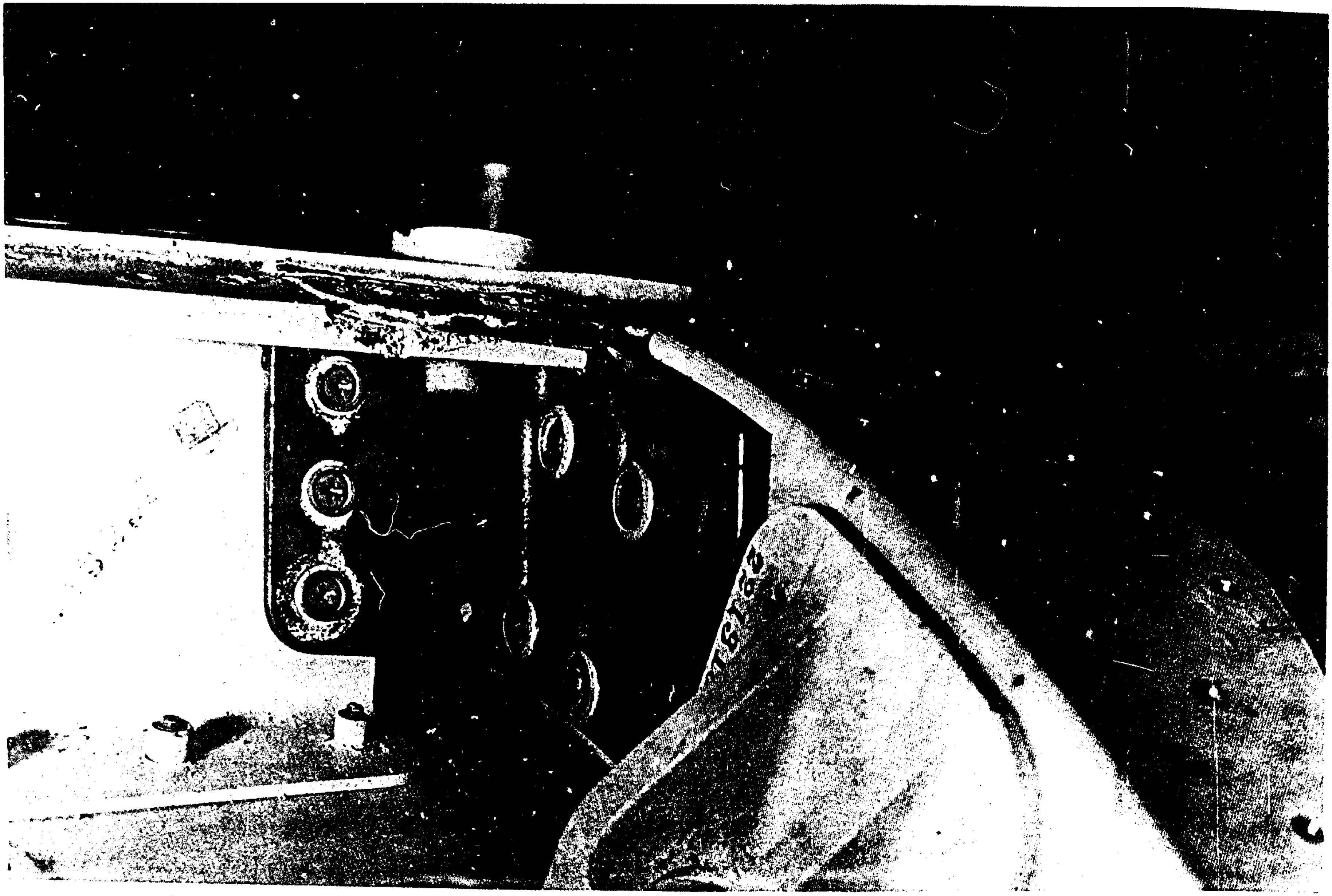

FIGURE 15 - Aft Mount From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Rust on Forward Shear Webs Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

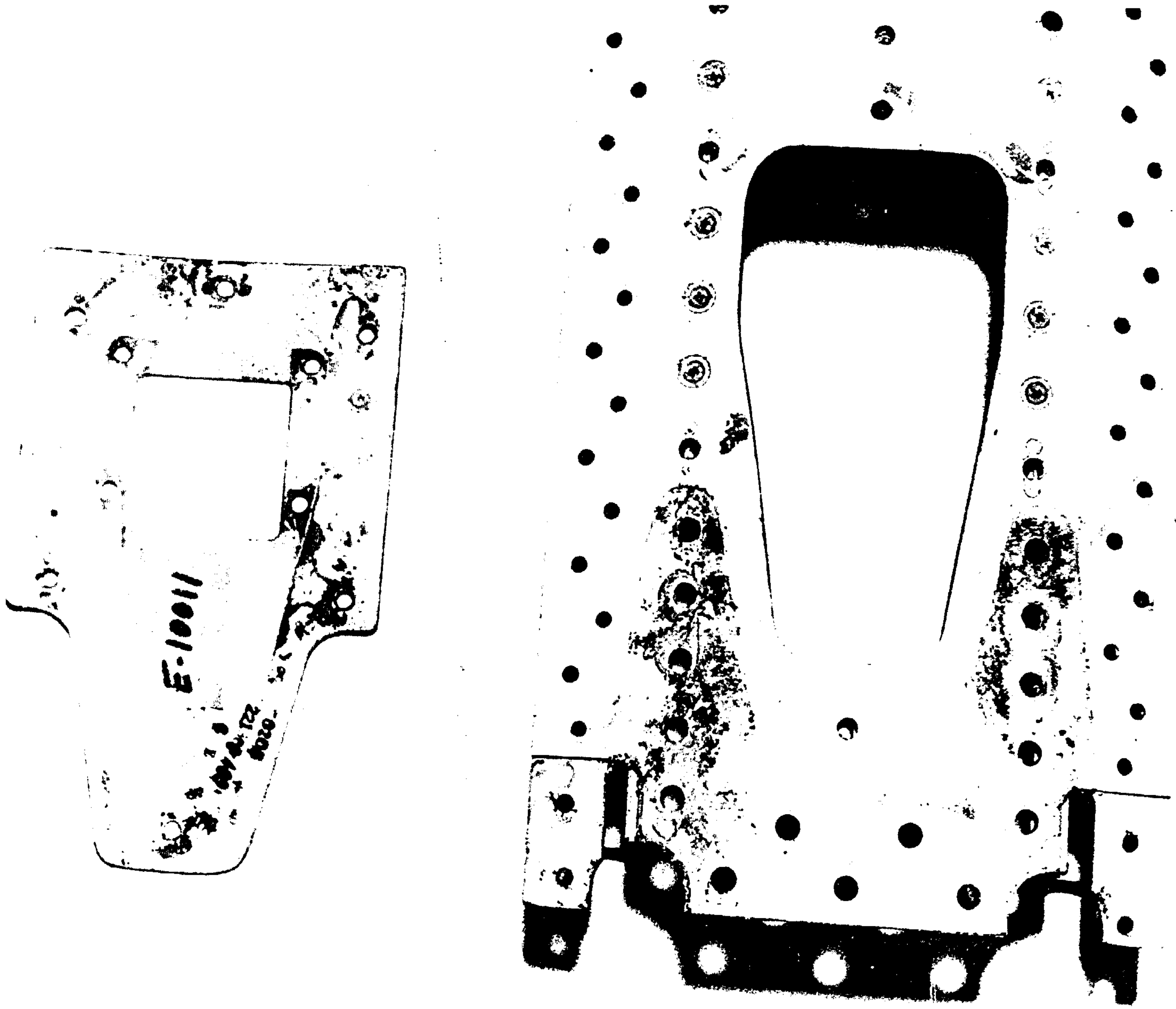

FIGURE 16 - Innercostal Doubler and Electrical Door From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Corrosion Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

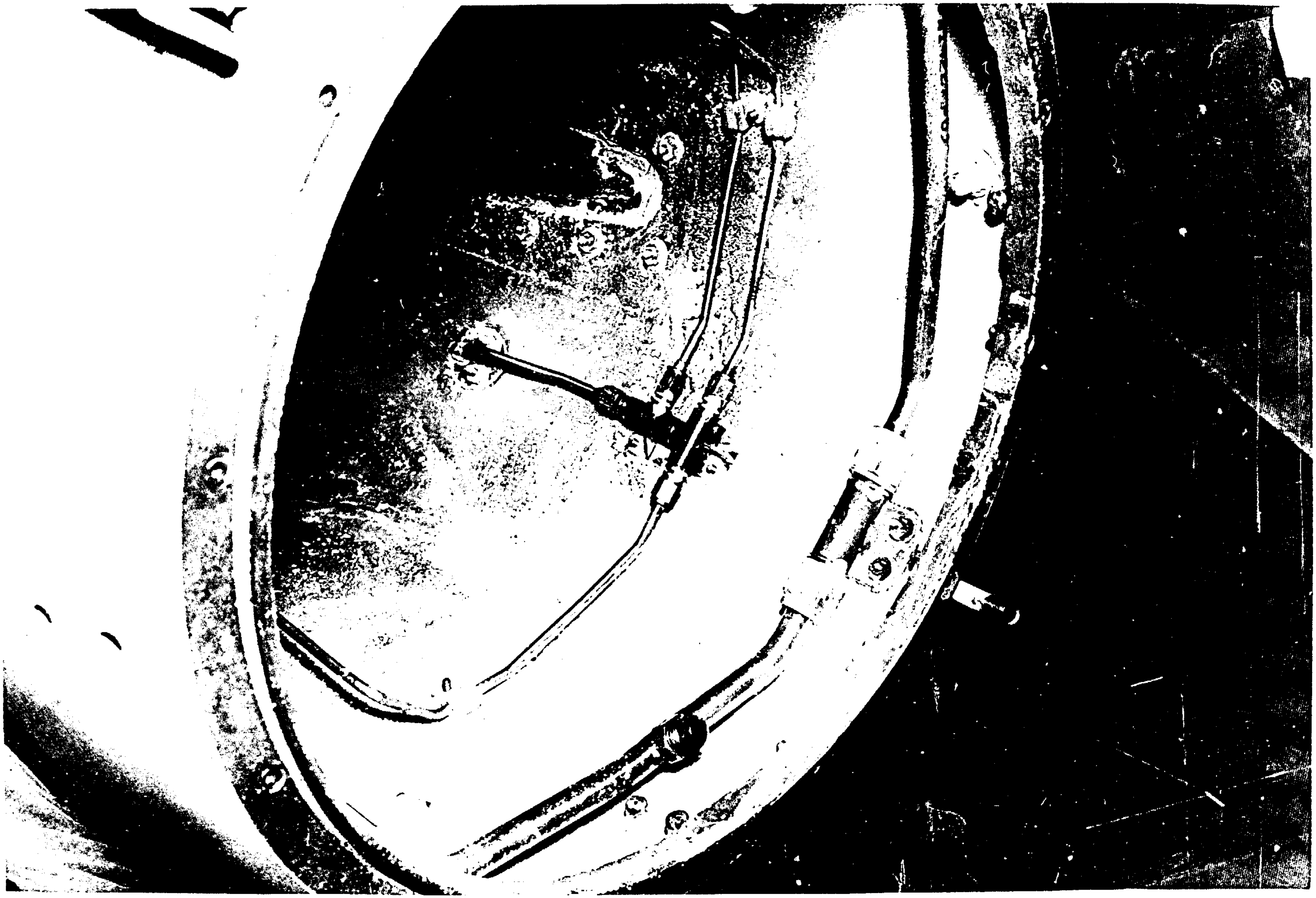

FIGURE 17 – Forward Innerbody Assembly From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Corrosion and Powdery Deposits Where Water had been Trapped During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

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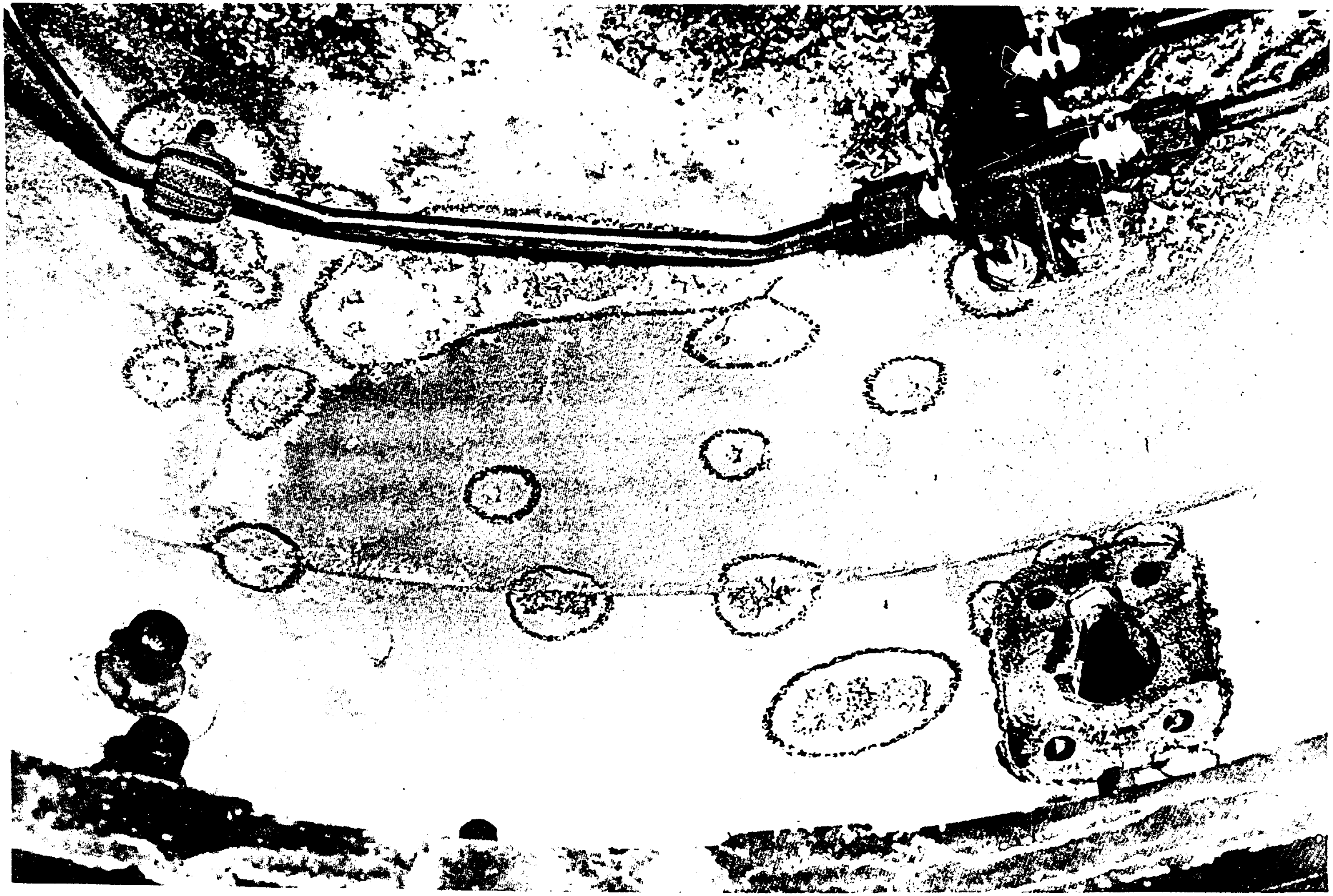

FIGURE 18 - Forward Innerbody Assembly From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Pitting and Corrosion Where Water had been Trapped During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

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FIGURE 19 - Aft Innerbody Assembly From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Magnesium Corrosion at Junctures with Steel Details, Rusted Spirolox Rings, and Corrosion of Aluminum Fuel Lines Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

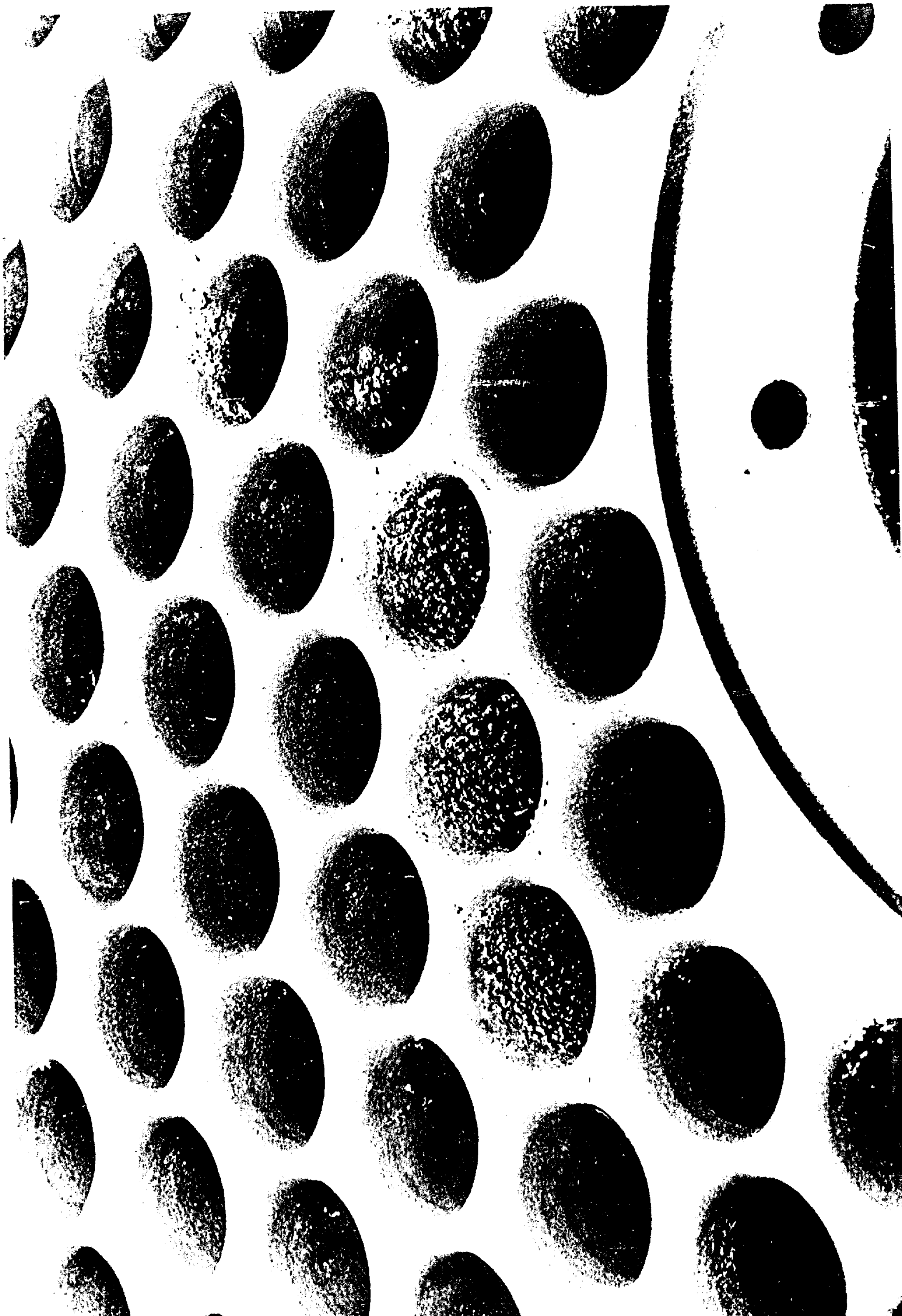

FIGURE 20 - Aerodynamic Grid From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Corrosion Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

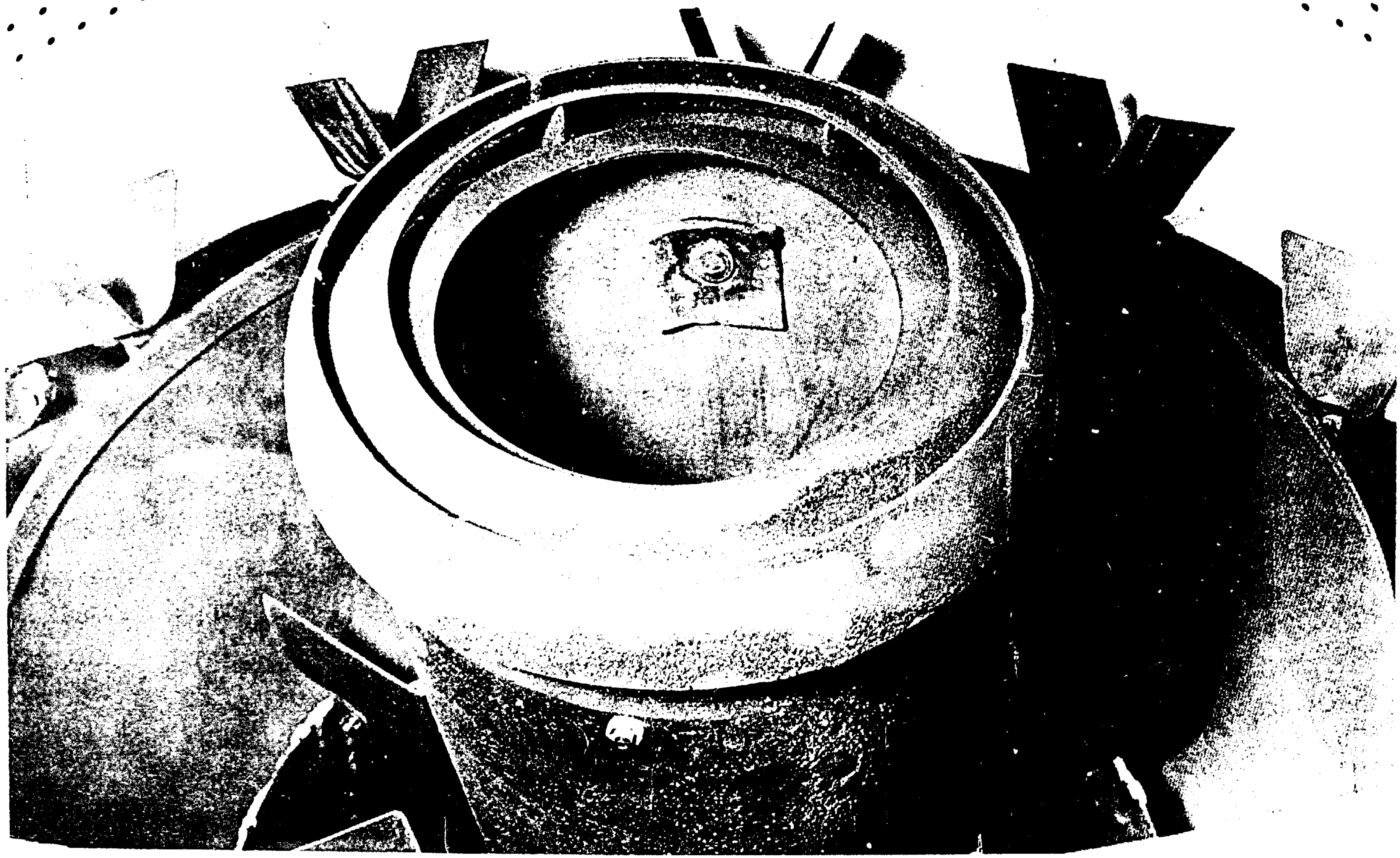

FIGURE 21 - Pilot Can and Inner Burner Assembly from RJ43-MA-11 Engine Serial MA-E10011-1 Showing Pyrochrome Paint Flaking Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

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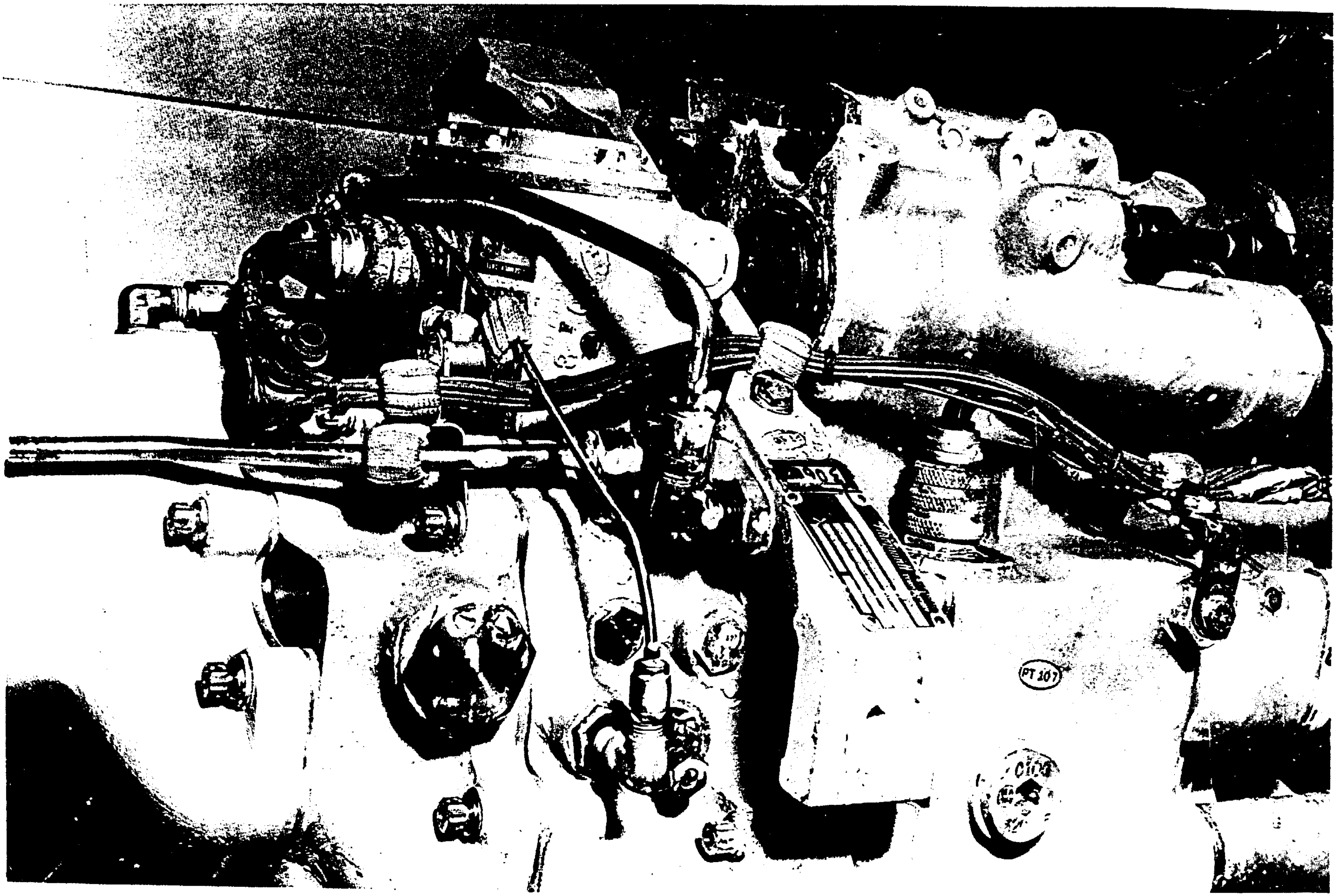

FIGURE 22 - Fuel Control Unit From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Corrosion at Junctures of Magnesium Castings and Seal Plates, Plugs, Fittings, etc., which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

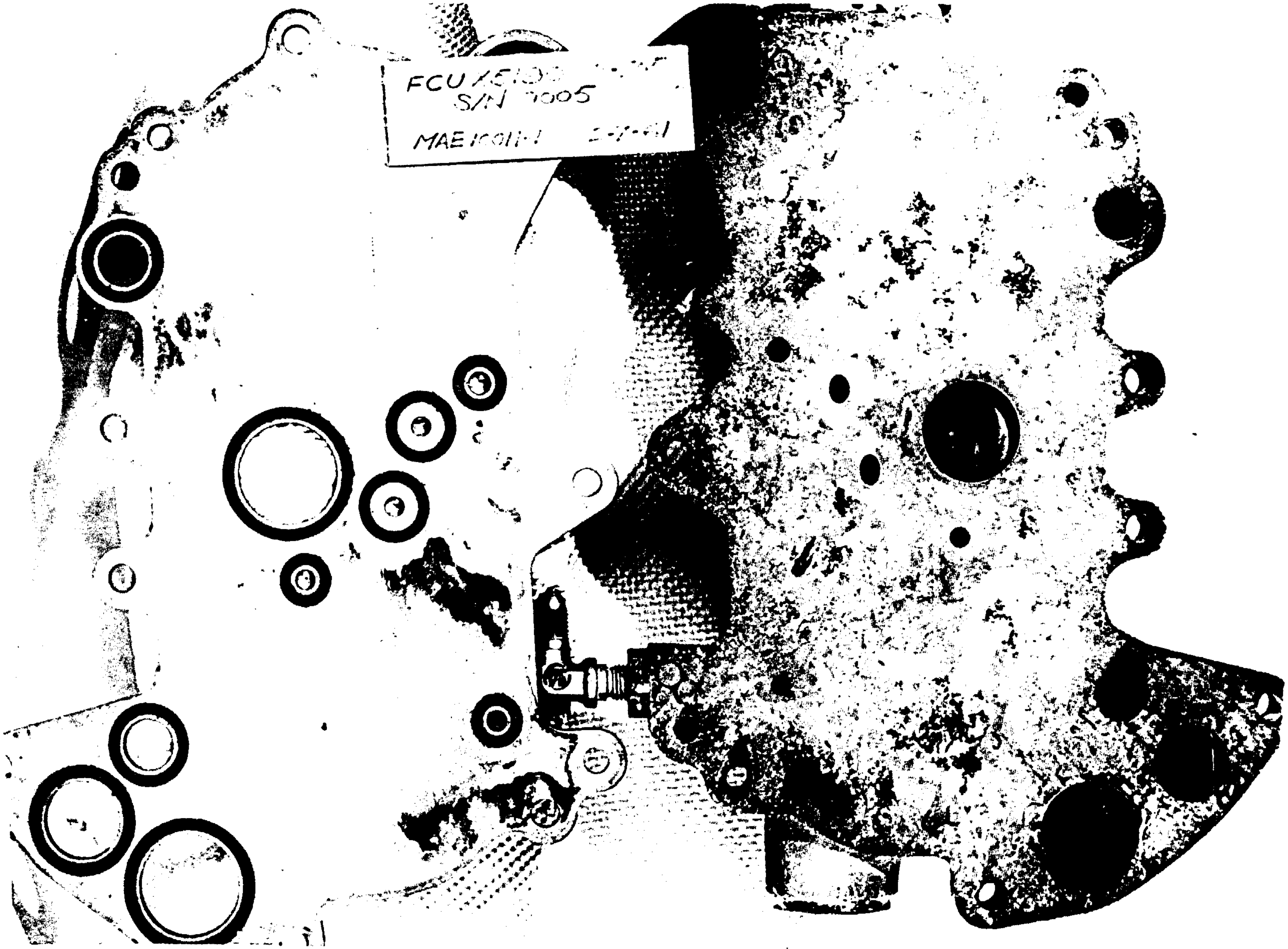

FIGURE 23 - Pressure Divider Assembly and Seal Plate From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Corrosion Deposits and Pitting Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

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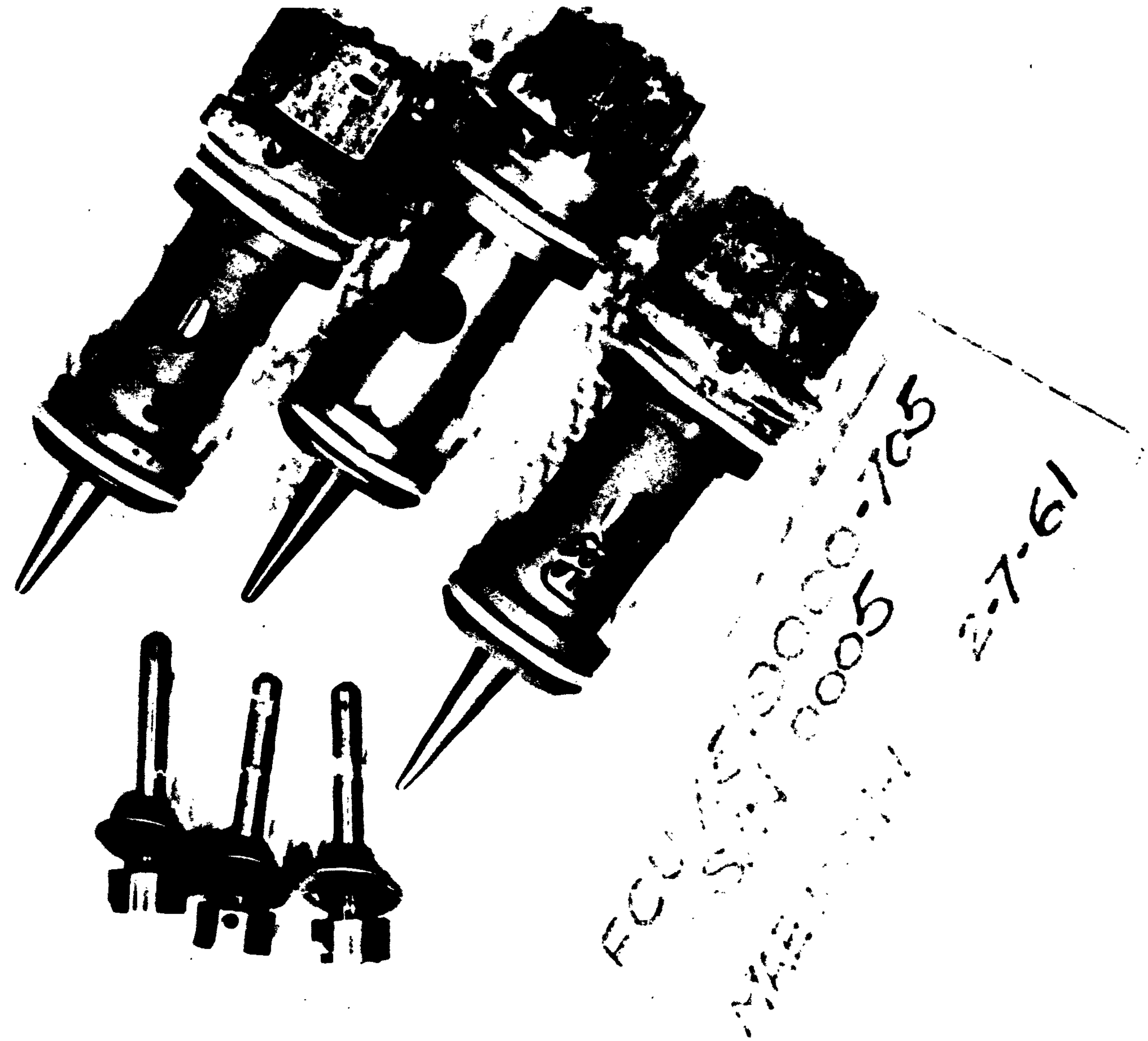

FIGURE 24 - Pressure Dividers and Lock Screws From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Corrosion Deposits and Pitting Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

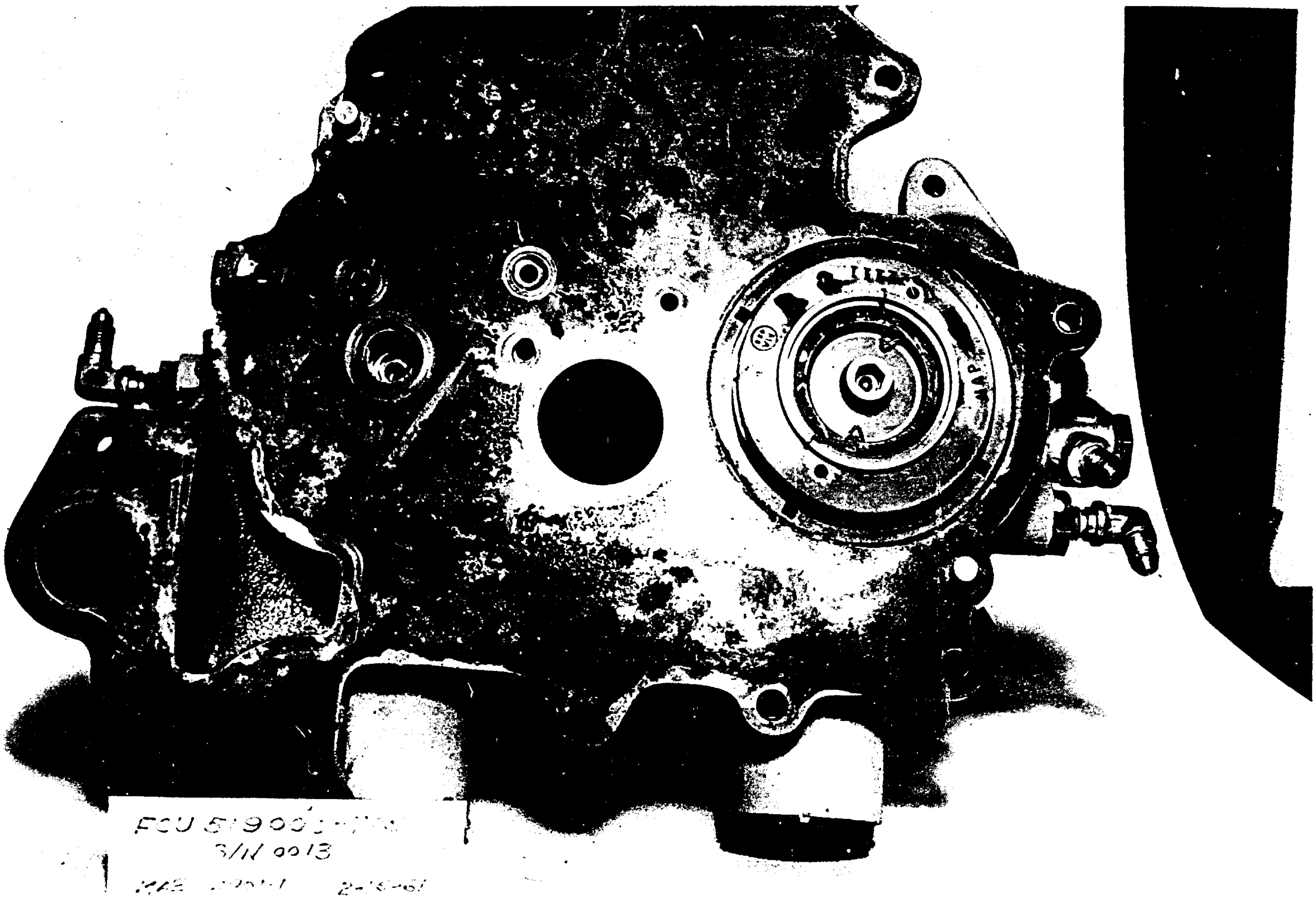

FIGURE 25 - Mach Senser-Shock Position Control Assembly From RJ43-MA-11 Engine Serial MA-E14901-1 Showing Aft Face Corrosion Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

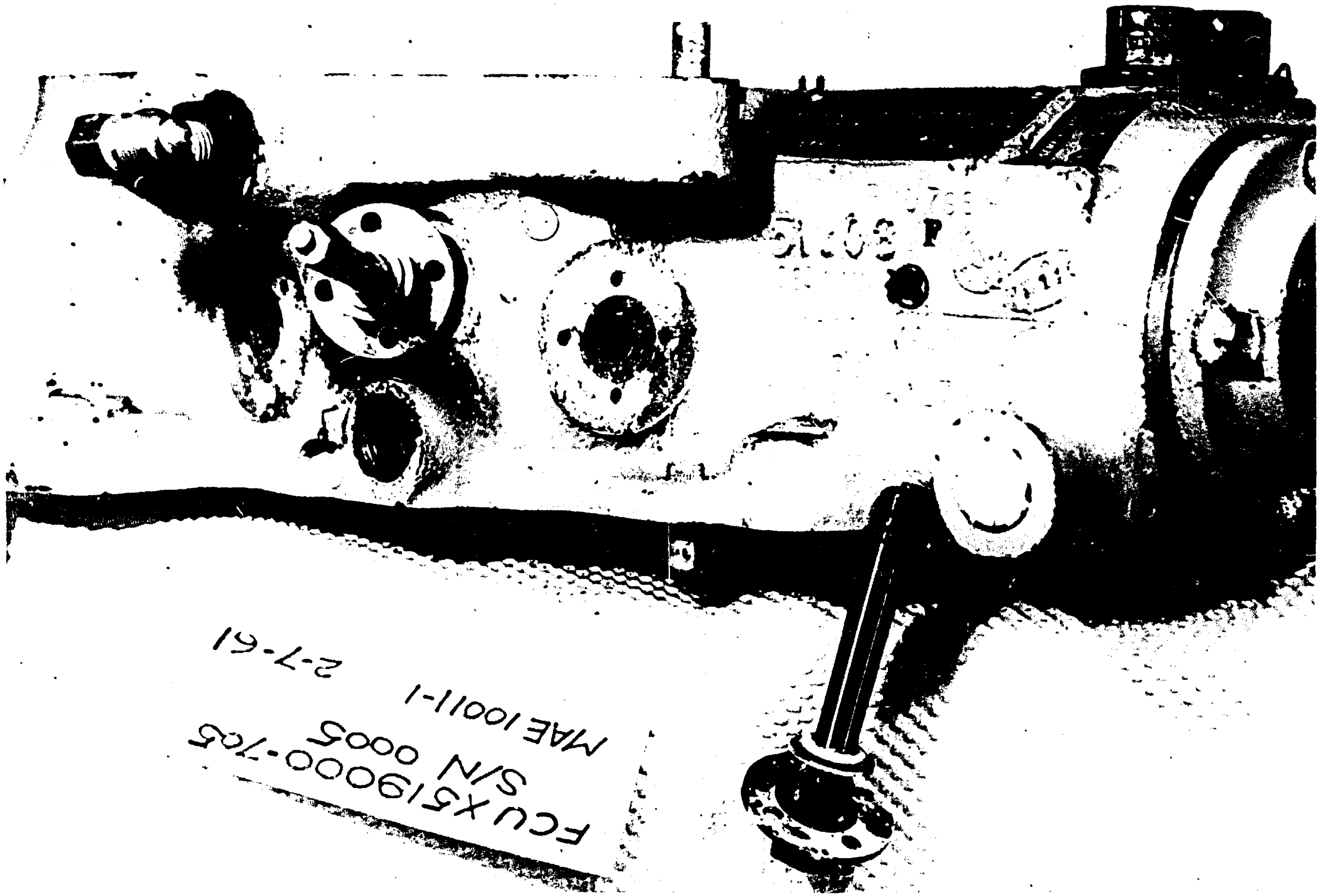

FIGURE 26 - Mach Senser-Shock Position Control Assembly From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Corrosion of Cam Retainers and Stops Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

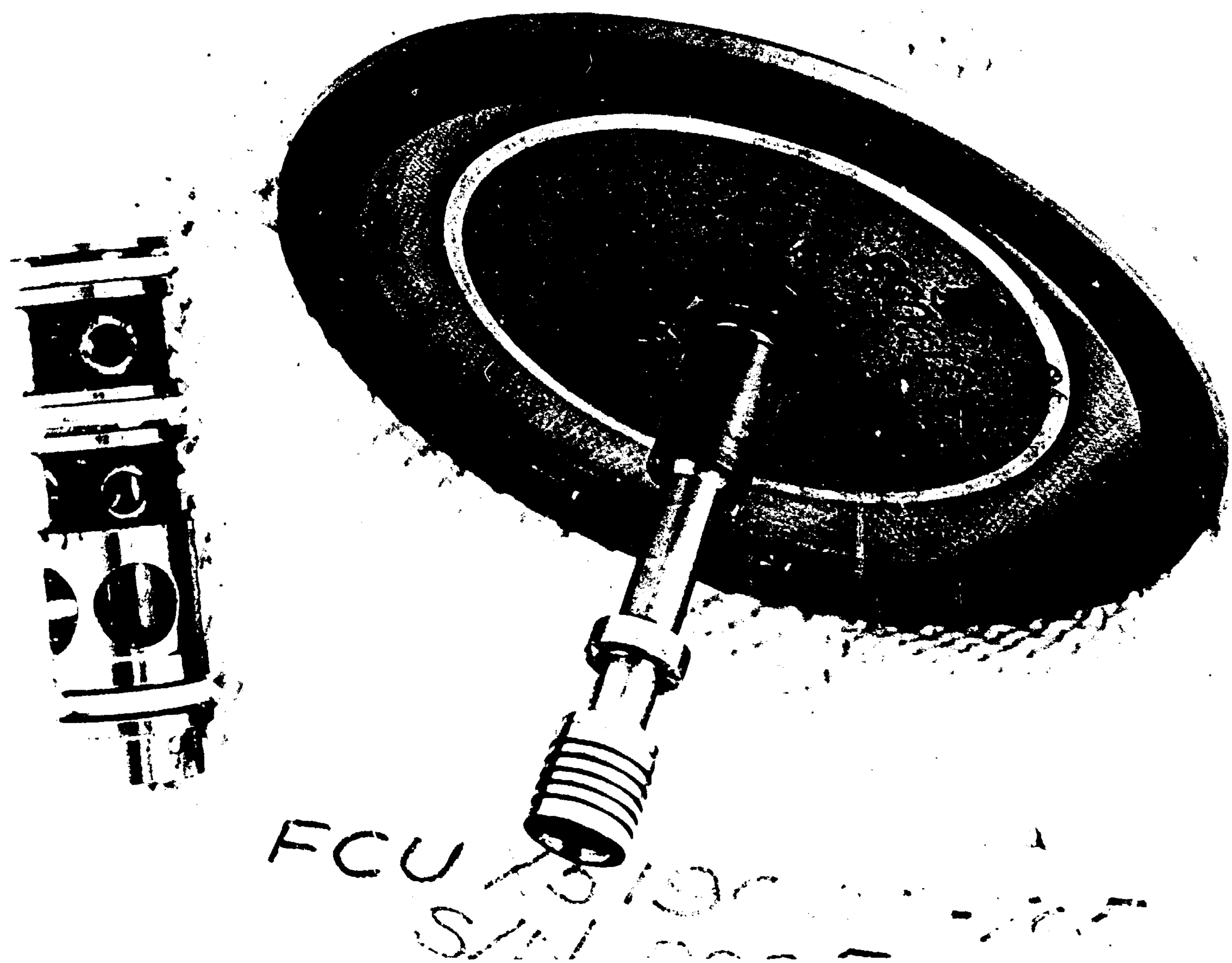

FIGURE 27 - Shock Positioner Valve-Sleeve Assembly and Diaphragm From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Corrosion Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

FIGURE 28 - Mach Senser Valve-Sleeve Assembly and Diaphragm from RJ43-MA-11 Engine Serial MA-E10011-1 Showing Corrosion and Diaphragm Disintegration Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

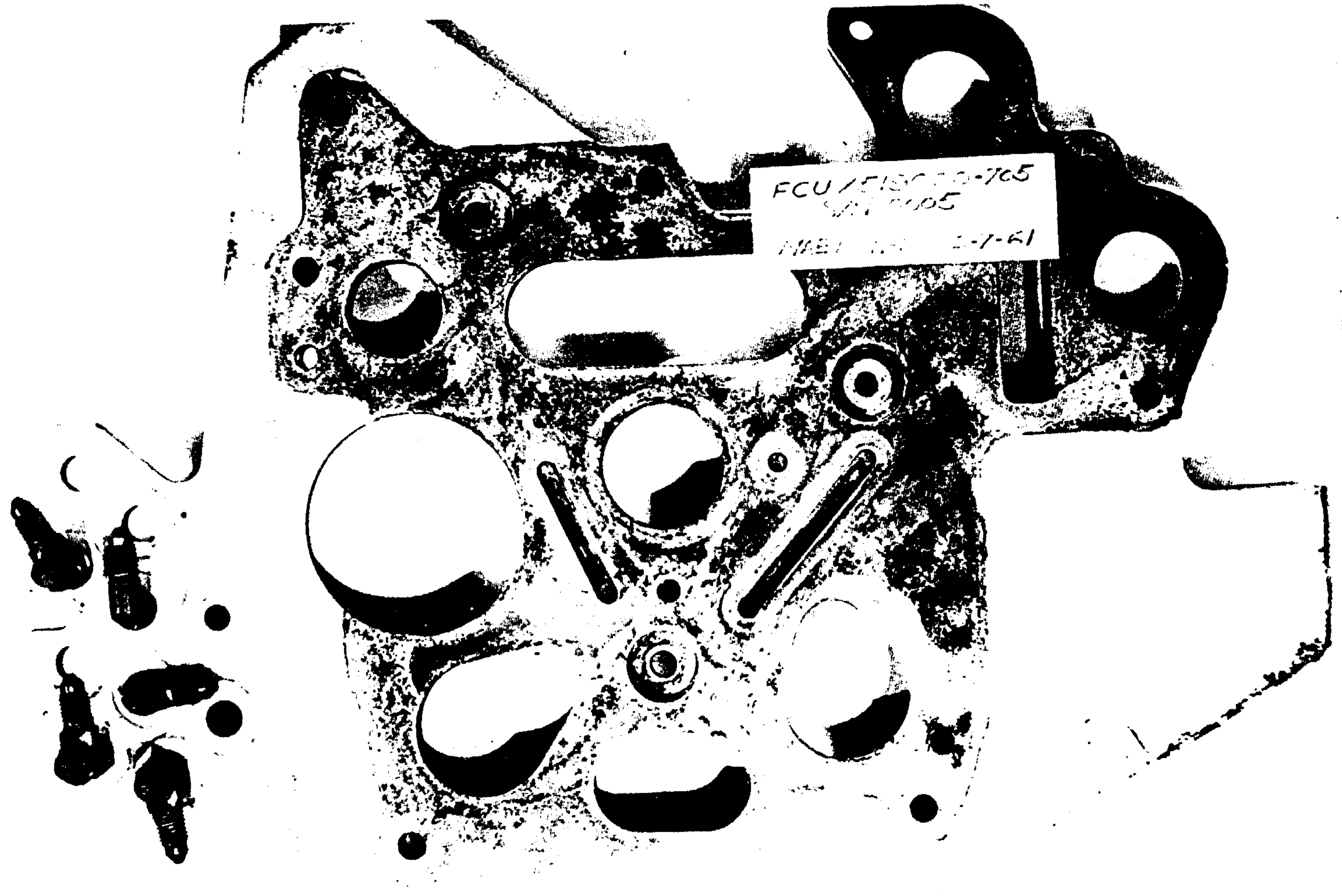

FIGURE 29 - Crossover Slab Assembly From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Aft Face Corrosion and Pitting Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

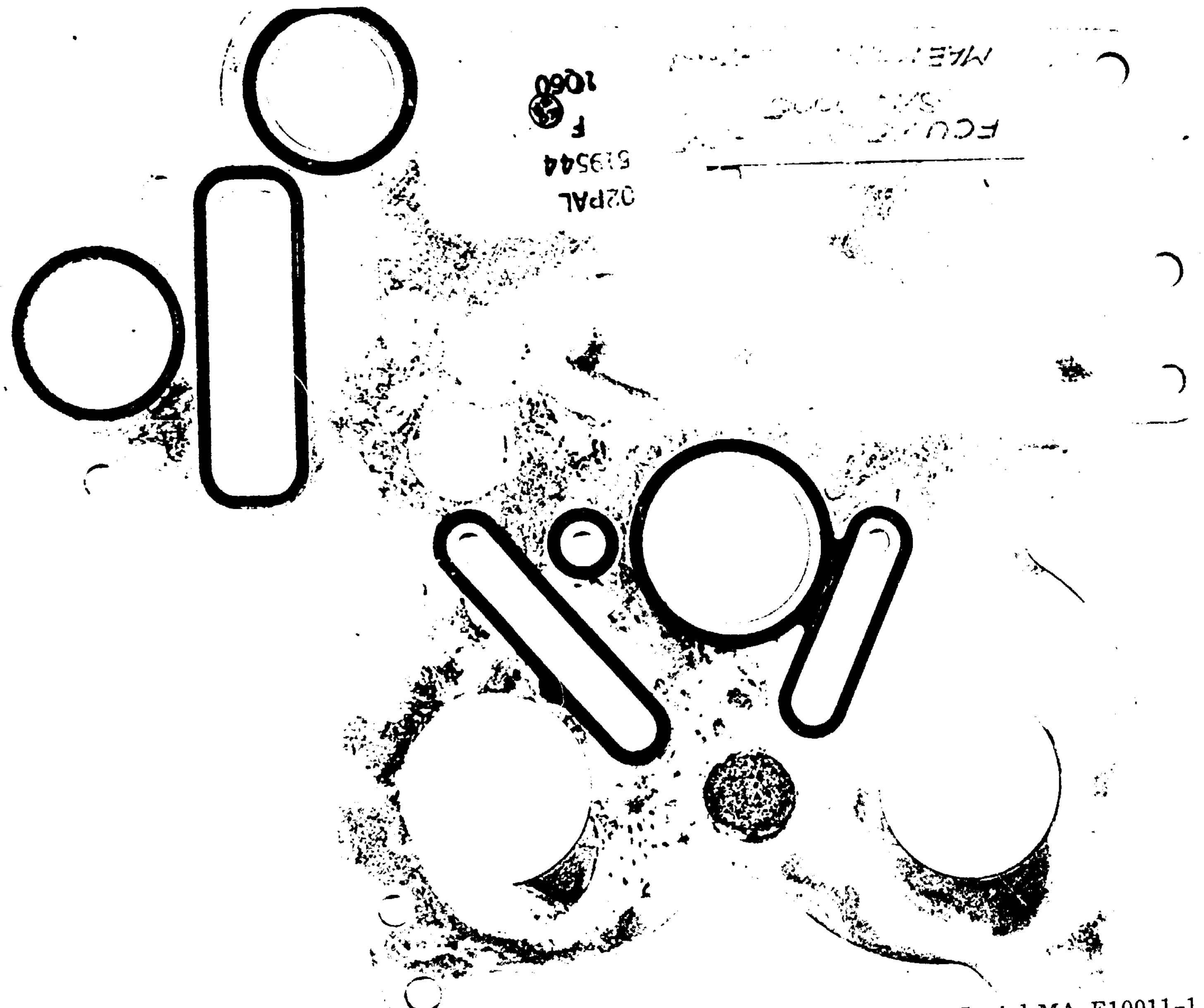

FIGURE 30 - Forward Flow Regulator Seal Plate from RJ43-MA-11 Engine Serial MA-E10011-1 Showing Forward Face Corrosion Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

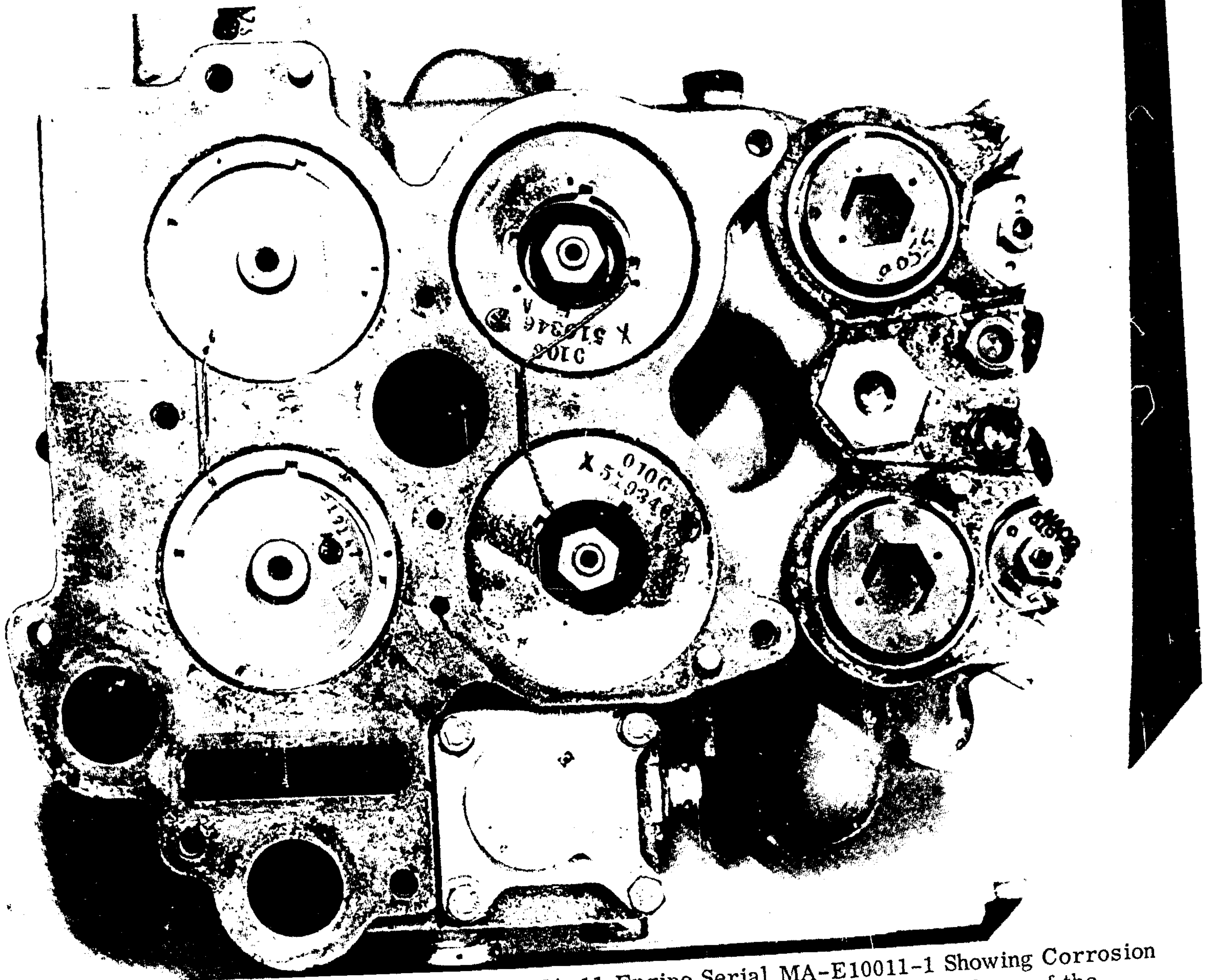

FIGURE 31 - Flow Regulator Assembly From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Corrosion Deposits on Forward Face Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

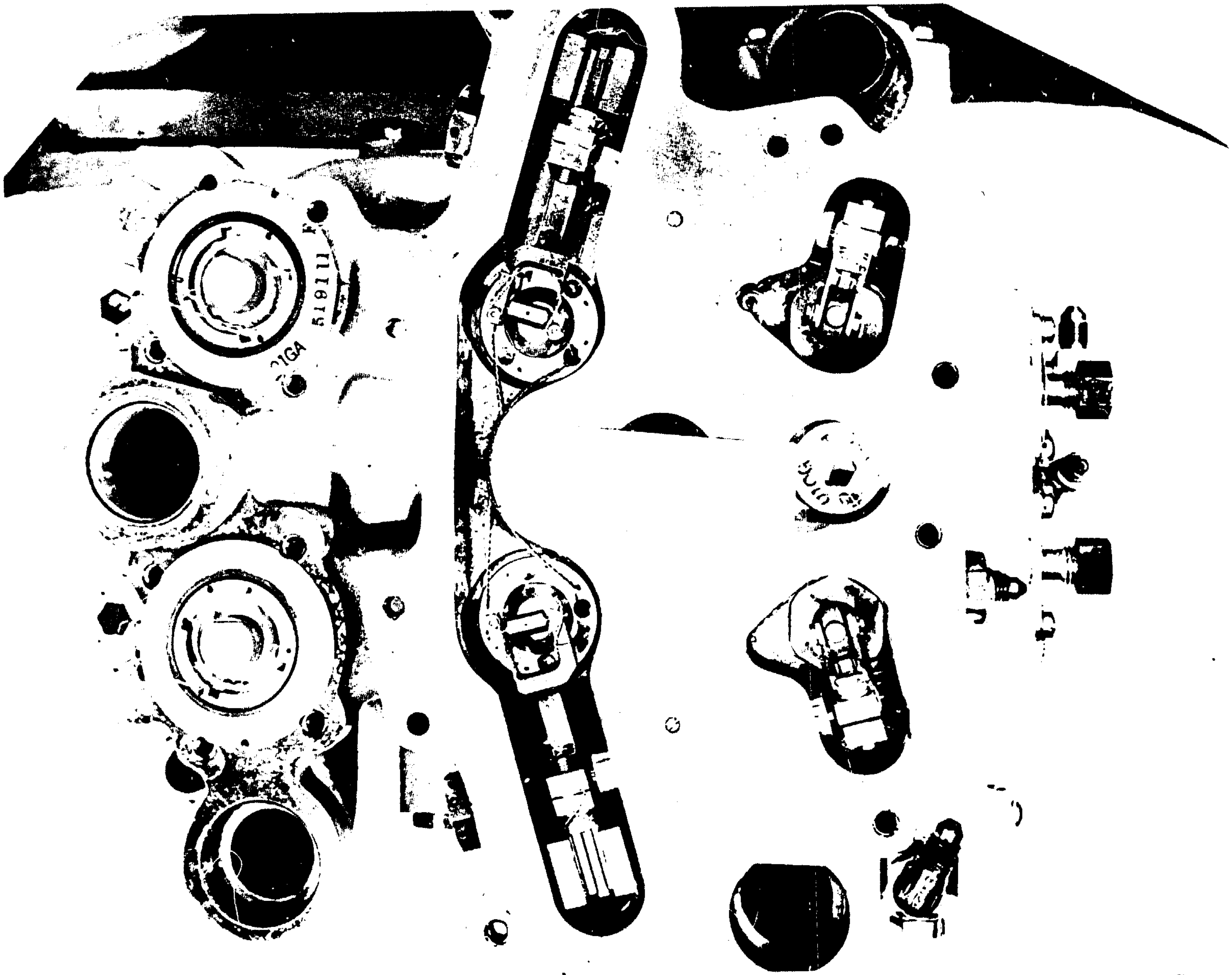

FIGURE 32 - Flow Regulator Assembly From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Corrosion on Aft Face and Pneumatic Details Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

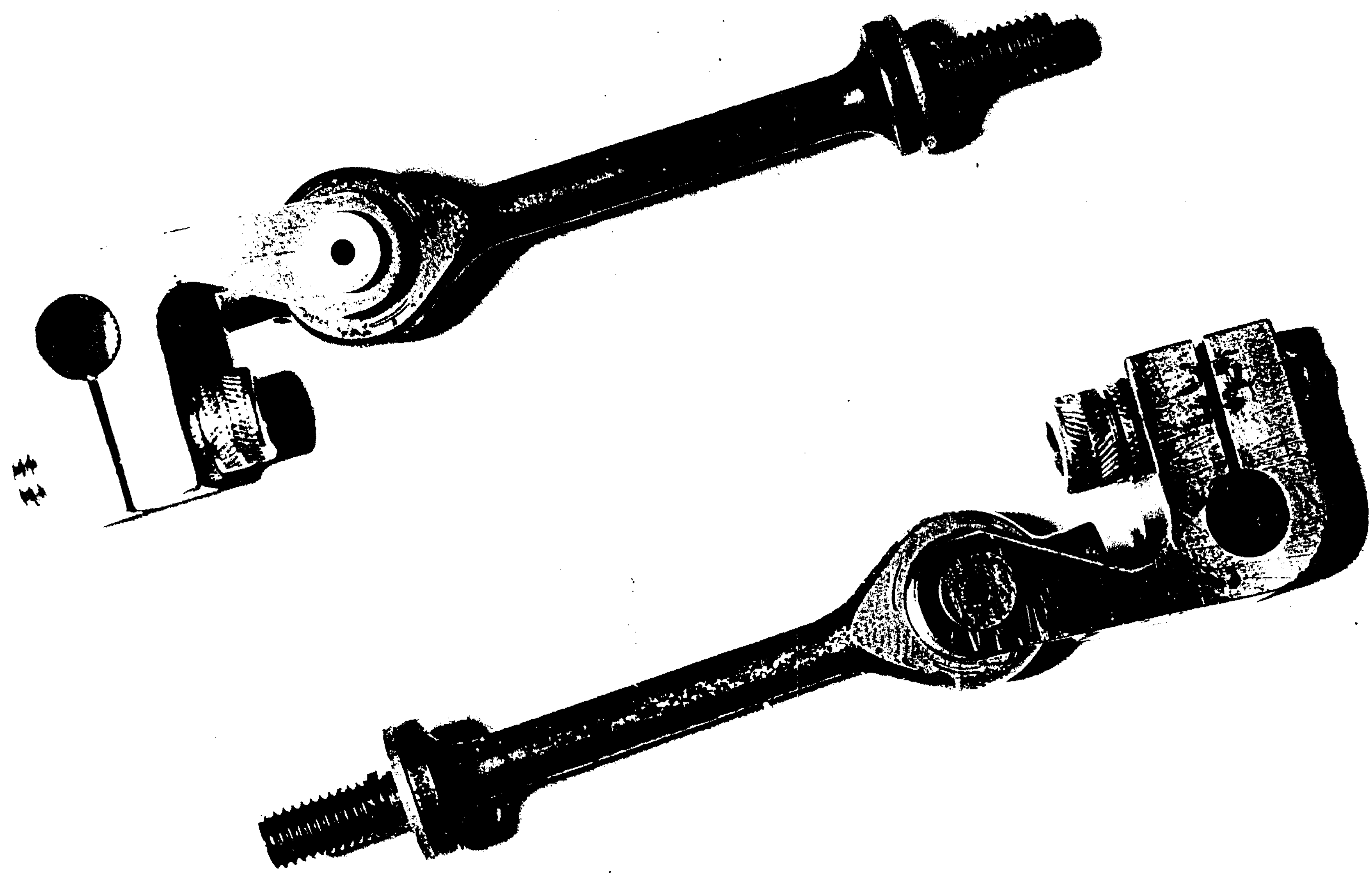

FIGURE 33- Flow Regulator Rocker Arm Assemblies from RJ43-MA-11 Engine Serial MA-E14901-1 Showing Corrosion on Rod-End Bearings Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

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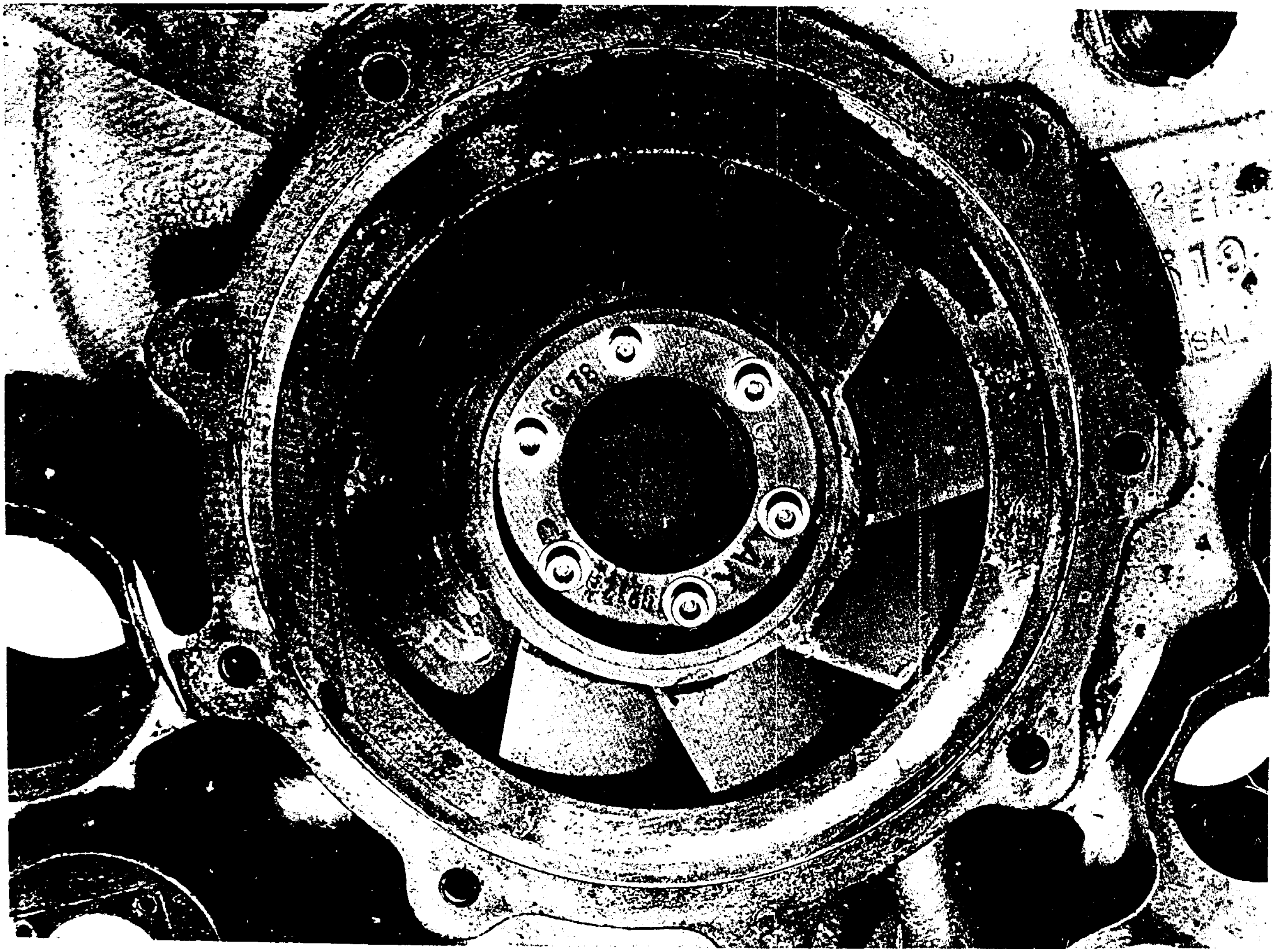

FIGURE 34 - Turbine Inlet Housing Assembly From RJ43-MA-11 Engine Serial MA-E14901-1 Showing Aft Face and Stator Corrosion Deposits Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

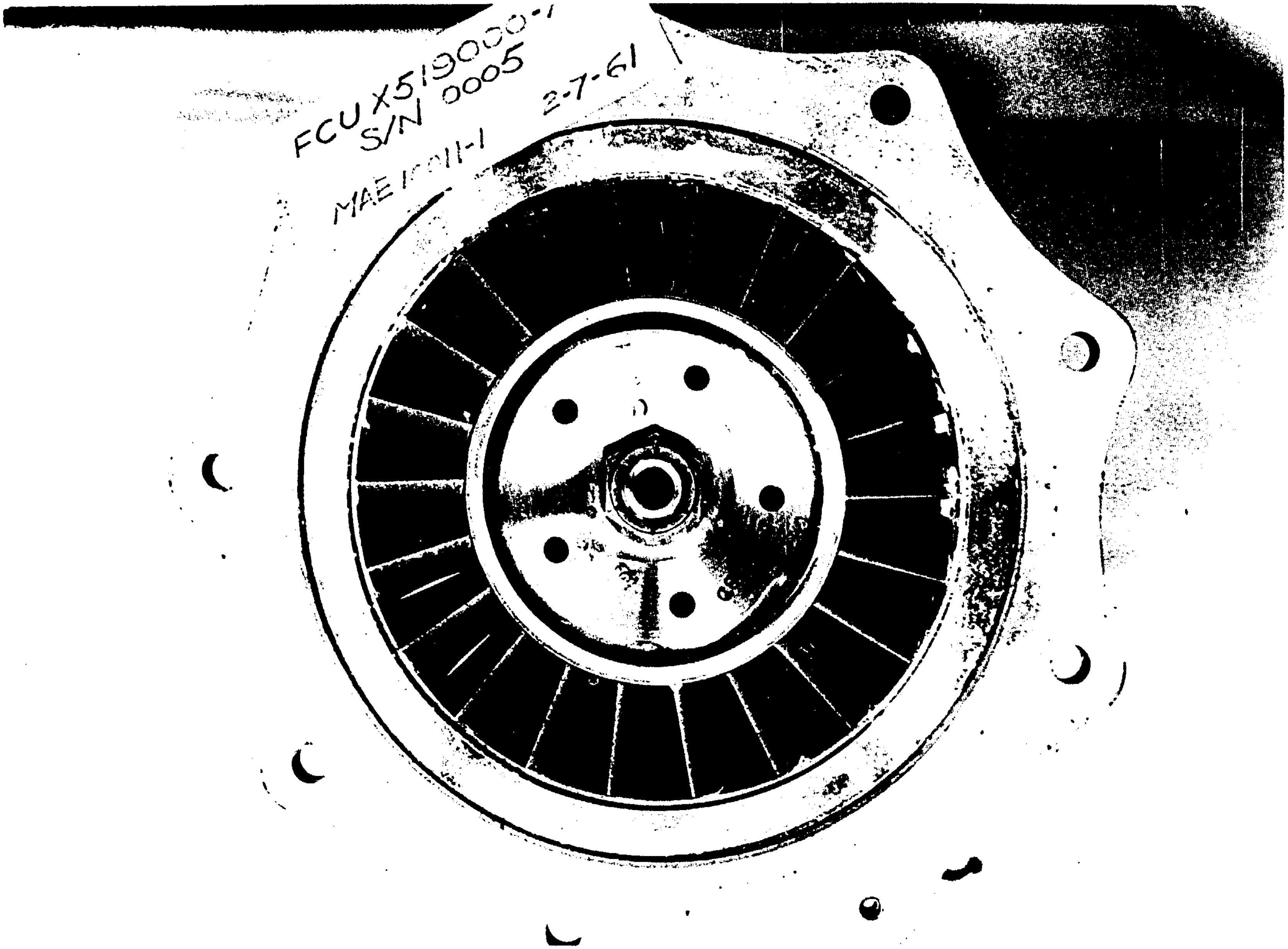

FIGURE 35 - Turbopump Balance Assembly From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Corrosion Buildup Between Rotor Tips and Stator Retainer Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

FIGURE 36 - First Stage Turbine Rotor From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Corrosion Deposits on Blade Tips Which Occurred During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

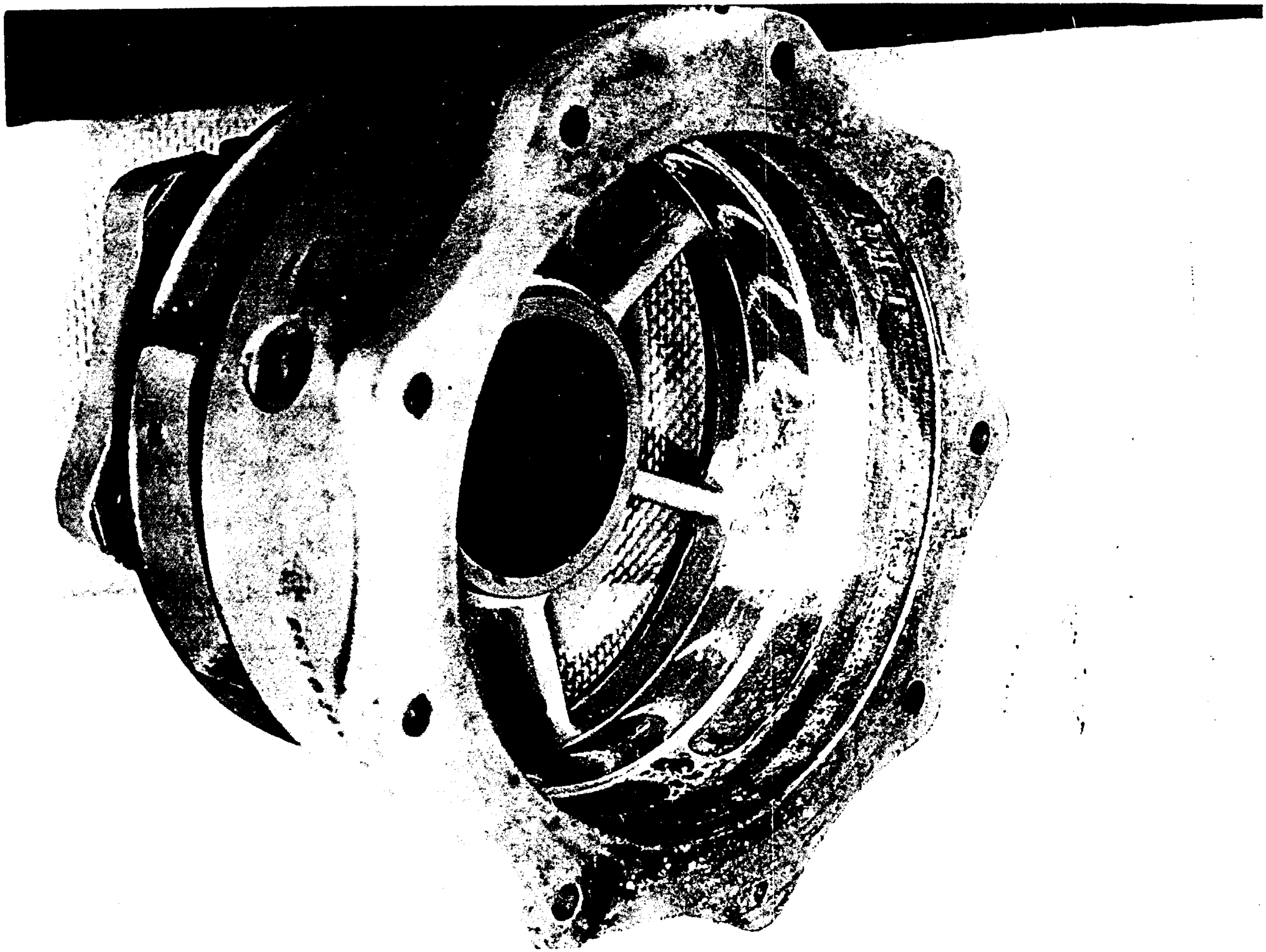

FIGURE 37 - Turbine Housing Assembly From RJ43-MA-11 Engine Serial MA-E10011-1 Showing Corrosion Deposits Where Water had been Trapped Inside Housing During the Accelerated Storage Phase of the RJ43-MA-11 Phase II Long-Term Storage Test.

V DISCUSSION OF REDIRECTED TEST PROGRAM

A. Test Plan

The test plan for the conduct of the redirected RJ43-MA-11 long-term environmental storage test program is basically the same as presented in Section III for the original program with the accelerated storage test and the periodic functional checks omitted. The test plan involved storing one flight-worthy RJ43-MA-11 engine in a simulated ready-storage environment and evaluating the effect of the storage environment on the performance and structural integrity of the engine. The individual tests planned to accomplish these objectives are listed below and will be discussed in detail later in this section of the report.

1. Engine prestorage operational test.
2. Long-term environmental storage test.
3. Poststorage evaluation of engine performance and structural integrity.

B. Test Item

The test item utilized in the Phase II redirected storage test program consisted of one flight-type RJ43-MA-11 engine identified as Serial MA-E10011-2. The engine was rebuilt to a basic production engine configuration (TMC P/N X221800) from parts salvaged from Serial MA-E10011-1 engine, spare development hardware and new production hardware. The fuel control unit installed in the engine was a former test unit, Serial 001, which was modified and refurbished for the storage test program. Both the engine and the fuel control unit incorporated the Class II corrosion preventative design changes discussed in Section IV.

The parts from engine Serial MA-E10011-1 which were found to be reusable and were incorporated into the new engine included the combustion chamber assembly, the $P_{26.5}$ pickup tubes and signal selectors, the front engine mount, and the titanium diffuser skin, Station 54.87 frame, and Station 42.12 frame illustrated in Figure 10. The engine was protected during the environmental test by pull-off protective covers obtained from Air Force personnel at Eglin Air Force Base. The tactical usage covers for the engine diffuser inlet, combustion chamber exit nozzle, and pneumatic exhaust tube are shown and identified in Figure 39. The engine was also protected with twelve bags of desiccant (desiccant content equal to 16 units per bag) stored inside the combustion chamber.

C. Engine Prestorage Operational Test

1. General

Prior to the initiation of the redirected environmental storage test, the test item was subjected to a comprehensive operational test to determine

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its compliance with the applicable specification governing the performance requirements of the test item. Data obtained during this test were to provide the criteria for checking satisfactory engine performance after the environmental storage test.

2. Test Procedure

The operational test conducted on the test item consisted of the normal MIL-Acceptance test conducted on all RJ43-MA-11 ramjet engines. The test included: (1) a preburn calibration test of the engine power control system, (2) combustion tests to evaluate the power control scheduling function and aerothermodynamic performance of the engine at simulated flight conditions, and (3) a postburn calibration recheck of the engine power control system.

The operational test was conducted at AF-MJL-O during July 1961 in accordance with Reference 3, Revision U.

3. Test Results

Results of the calibration and combustion tests conducted on engine Serial MA-E10011-2 met all requirements of Reference 3, Revision U. The final prestorage calibration data are presented in Figures 50 through 52 and Table V.

D. Long-Term Environmental Storage Test

1. General

A 24-month period of storage in an environment representative of that found inside IM-99B launcher-shelters was conducted to assist in the evaluation of RJ43-MA-11 engine design life, to provide the data necessary to determine if the two-year interval between functional confidence checks is compatible with the design of the power control system, and to determine what elements, if any, may be troublesome in operational usage of the engine.

2. Test Procedures

The test engine was stored inside an enclosure where the temperature and humidity environment of an IM-99B launcher-shelter could be duplicated. The anticipated temperature within a launcher-shelter is 60°F to 125°F and humidity is uncontrolled. Temperature and relative humidity were continuously recorded on a Foxboro recording instrument during the two-year storage period. Engine desiccant was monitored and the desiccant was replaced as required. Periodic visual inspections of the engine were conducted.

Engine Serial MA-E10011-2 was initially stored in a corner of the AF-MJL-O free-jet test cell exhauster building as shown in Figure 38. This site provided an environment characterized by frequent cycles and large amplitude changes in temperature and humidity due to the operation of the exhausters. The engine was stored at this location from August 1961 to November 1962. In November 1962 production of the RJ43-MA-11 engine stopped and AF-MJL-O was deactivated. The test engine was moved to a new storage location at the Marquardt-Ogden main plant. The new storage enclosure, shown in Figure 39, was located outdoors so that temperature and humidity generally followed the outside environment variation. A thermostat-controlled gas heater was provided to maintain a stabilized lower temperature level within the enclosure. The engine remained at this storage site until the test ended in August 1963.

3. Test Results

Figure 40 presents the weekly high and low temperature and relative humidity readings recorded in the storage areas during the two-year storage test. It will be noted that the temperature could not be continuously maintained above 60°F in the storage areas during the cold winter months. The lowest temperatures were, in general, 20°F lower than anticipated in actual tactical usage. This provided a somewhat more severe test than required. Figure 40 also indicates when the desiccant inside the engine required replacement. A histogram of temperature and relative humidity is presented in Figure 41.

Superficial periodic inspections of the engine structure revealed no change in the structural condition of the engine during the two-year storage period.

E. Engine Poststorage Evaluation

1. General

The effect of the ready-storage environment on engine performance and structural integrity was evaluated by: (1) a combustion test to demonstrate engine ignition performance, (2) a recheck of the engine power control system calibration, and (3) complete disassembly of the test engine to inspect for corrosion or similar forms of deterioration.

2. Test Procedures

a. Combustion Test

The purpose of the poststorage combustion test was to demonstrate the capability of the RJ43-MA-11 engine to ignite when launched directly from its stored condition following a long period of ready-storage. Normal test procedures usually include a cold flow test run prior to the test firing to verify proper installation of the engine in the test cell, to verify proper engine fuel scheduling, to finalize test procedures, to provide practice for test personnel in the actual execution of their varied duties, and to reveal any problems which could jeopardize the test firing. This procedure was not followed before the ignition demonstration run because it would have invalidated the simulation of immediate launch of the engine from its stored condition. Instead, extra precautions were taken during the test setup and special coordination of individual test procedures was provided to assure a high probability of success on the first test firing attempt.

The combustion test was conducted in free-jet Test Cell No. 3 at the Air Force-Marquardt Jet Laboratory-Van Nuys, California, during September 1963. The test setup is shown in Figure 42. Test procedures were followed which provided air flow from a sonic free-jet nozzle to the engine inlet at free-stream pressure and temperature conditions which would be experienced during a Mach number traverse from zero to one at test site altitude ($\approx$700 feet) and ARDC-STANDARD temperature day simulation. The launch to Mach one was performed in approximately 10 seconds with an additional 10-second period of burning at a stabilized Mach one test condition before the engine was shut down.

Two forty-five second M-114 flares were used as the ignition source. Fuel was supplied to the engine at 75 psig. Increased minimum power fuel flow was scheduled by the engine power control system in a "hands off" operation which utilized the aspiration effect on the pneumatic exhaust slash tube to provide fuel scheduling inputs as they would occur during an actual missile launch. Engine diffuser static pressure instrumentation provided the ignition indicating parameter.

Engine and facility pressure, temperature, and flow parameters were recorded during the test run on oscillograph tape. Visual data were obtained during the run by gauges and indicators which were periodically photographed to provide backup data. The test run was witnessed by representatives from the Air Force Quality Control office at the Marquardt-Van Nuys plant.

b. Power Control System Calibration Test

The poststorage power control system calibration check was performed in accordance with the postburn calibration portion of Reference 3, Revision U. The test was conducted at the Marquardt-Ogden main plant in October 1963. The facility for testing the power control system at the TMC-Ogden main plant would not readily accommodate the entire engine structure so the fuel control unit was removed from the engine for the test. Interface pneumatic and hydraulic connections between the engine and fuel control unit were pressure checked before the fuel control was removed. Special pneumatic adapters and

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actual engine structure hardware were plumbed into the fuel control test setup to provide pressure drop and response characteristics equivalent to performance with the fuel control unit installed in the engine. The setup for the calibration test is shown in Figure 43.

c. Engine Disassembly and Inspection

The structural evaluation of the engine was conducted at the Marquardt-Ogden main plant in October 1963. The engine structure and the fuel control unit were disassembled to the extent that any corrosion or deterioration present could be detected. The disassembled hardware is shown in Figures 44 through 46. The disassembly was conducted under the cognizance of a representative from the Marquardt-Ogden Air Force Quality Control office. Each part was given a final inspection by a committee composed of representatives from the Air Force Quality Control office, Marquardt Quality Control Department, and Marquardt Engineering Department.

3. Test Results

a. Combustion Test

The first combustion test firing attempted met all test objectives and was completely successful. Reduction of the test data acquired during the firing showed that ignition occurred at Mach 0.62. The point of ignition is shown in Figure 47 where the diffuser static pressure ratio, P_{82}/Pt_o, deviates from the estimated cold flow variation. Marquardt Specification 5602E, (Reference 7), Model Specification for the RJ43-MA-11 Ramjet Engine (Marquardt Model MA20ZS-3), requires that the "Engine ignition on increased minimum power shall occur by a Mach number of 0.80."

The engine sustained practically no burn damage during the firing. Normal discolorization and slight erosion of the CP-44 ceramic paint on the outer burner assembly occurred as illustrated by Figure 48. The excellent general condition of the engine structure following the firing is shown by Figure 49.

b. Power Control System Calibration Test

The data obtained from the poststorage calibration test of the power control system showed excellent overall agreement with the prestorage calibration data. All data remained within the calibration requirements of Reference 3, Revision U. A comparison of the prestorage and poststorage data for the overall power control system calibration, Mach senser calibration, shock position control calibration, and dynamic response data are shown in Figures 50 through 52 and Table V.

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Functional tests of the signal selector valve system and fuel transfer valve and pneumatic and hydraulic leakage checks were satisfactory.

c. Engine Disassembly and Inspection

Engine Serial MA-E10011-2 and its associated fuel control unit, Serial 001, when disassembled, were found to be in excellent condition. No significant corrosion or deterioration was discovered on metal details. O-rings and seals showed little or no permanent set. Lubricants and bearing grease showed no signs of deterioration.

TABLE V

RJ43-MA-11 RAMJET ENGINE SERIAL MA-E10011-2 DYNAMIC RESPONSE DATA SHEET

Item			Required Dynamic Response Test Check Points	Pre-Storage	Post Storage	Allowed
$P_{26.5}$ DYNAMIC RESPONSE TEST	$P_{26.5}$ STEP INPUT	A	Overshoot	0%	0%	≤ 12%
		B	Rise Time — Time to 50% before overshoot	0.06 sec.	0.015 sec.	≤ 0.15 sec.
		C	Final Value Time — time required to reach and remain within ± 10% of final value	0.14 sec.	0.03 sec.	≤ 0.50 sec.
	W_{f_t} RESPONSE	A	Dead Time	0.04 sec.	0.04 sec.	≤ 0.30 sec.
		B	Overshoot	14%	5%	≤ 15%
		C	50% Response Time before overshoot	0.10 sec.	0.11 sec.	≤ 0.50 sec.
		D	Final Value Time — time to reach and remain within $^{+0}_{-20}$% of final value	0.14 sec.	0.15 sec.	≤ .85 sec.
$P_{t_{1.4}}$ DYNAMIC RESPONSE TEST	$P_{t_{1.4}}$ STEP INPUT	A	Rise Time — time to 50% value before overshoot	0.09 sec.	0.03 sec.	≤ 0.15 sec.
		B	Final Value Time — time to reach and remain within ± 10% of final value	0.26 sec.	0.08 sec.	≤ 0.40 sec.
	W_{f_t} RESPONSE	A	Dead Time	0.05 sec.	0.10 sec.	≤ 0.20 sec.
		B	Overshoot	3%	0%	≤ 15%
		C	50% Response Time before overshoot	0.20 sec.	0.23 sec.	≤ 0.25 sec.
		D	90% Response Time before overshoot	0.33 sec.	0.35 sec.	≤ 0.40 sec.
		E	Final Value Time — time required to reach and remain within ± 10% of final value	0.33 sec.	0.35 sec.	≤ 0.65 sec.
P_{t_6} DYNAMIC RESPONSE TEST	P_{t_6} STEP INPUT	A	Overshoot	1%	3%	≤ 12%
		B	50% Response Time before overshoot	0.02 sec.	0.01 sec.	≤ 0.20 sec.
		C	Final Value Time — time to reach and remain within ± 10% of final value	0.05 sec.	0.03 sec.	≤ 0.40 sec.
	W_{f_t} RESPONSE	A	Dead Time	0.09 sec.	0.06 sec.	≤ 0.30 sec.
		B	Overshoot	0%	0%	≤ 15%
		C	50% Response Time before overshoot	0.20 sec.	0.15 sec.	≤ 0.50 sec.
		D	Final Value Time — time required to reach and remain within $^{+0}_{-20}$% of final value	0.39 sec.	0.21 sec.	≤ 0.85 sec.

NOTE: All times are measured from the zero time point of the step input.

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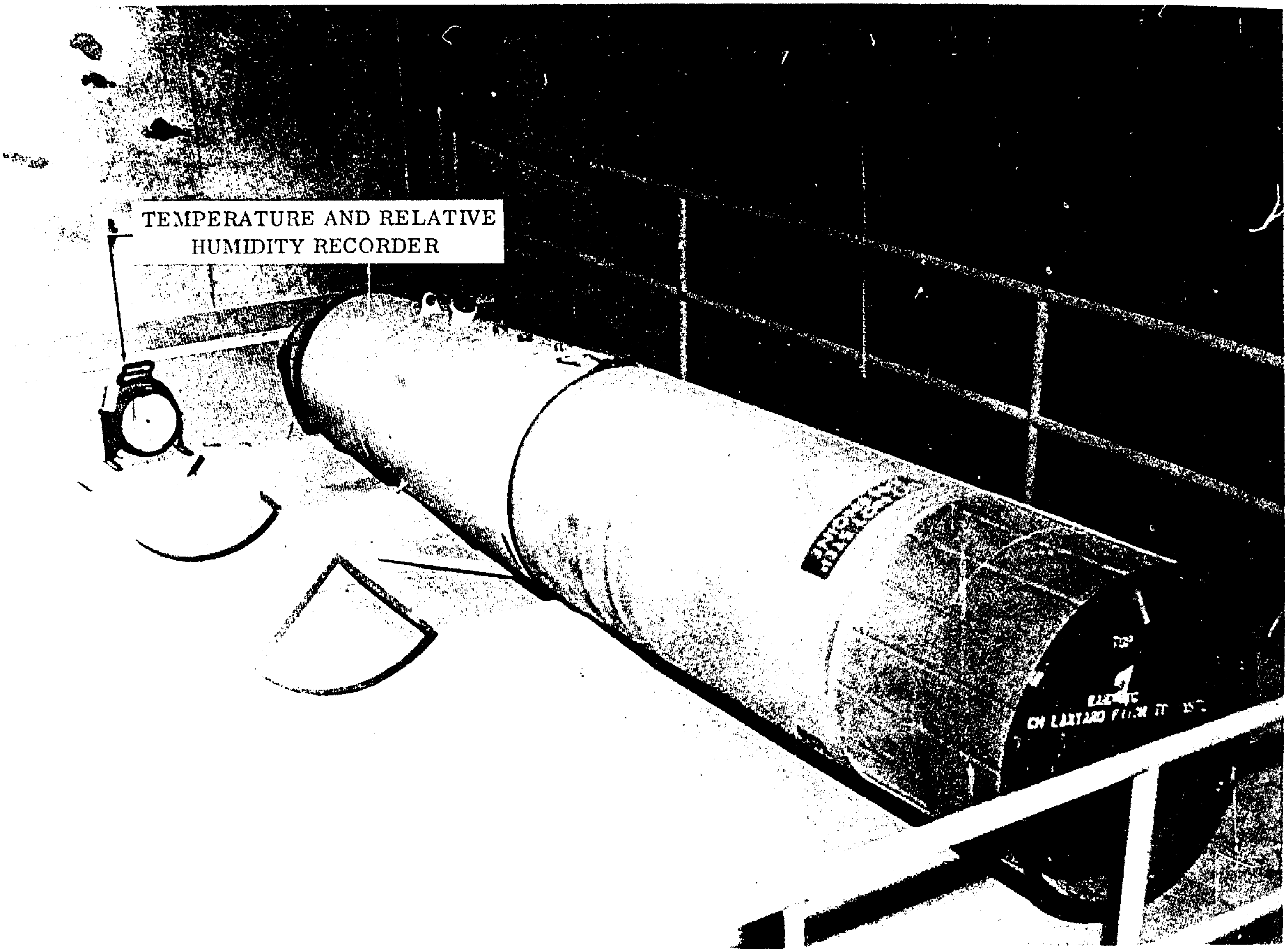

FIGURE 38 - Storage Site, From August 1961 to November 1962, For the RJ43-MA-11 Phase II Long-Term Storage Engine Serial MA-E10011-2. Area is located at the Air Force-Marquardt Jet Laboratory-Ogden, Utah.

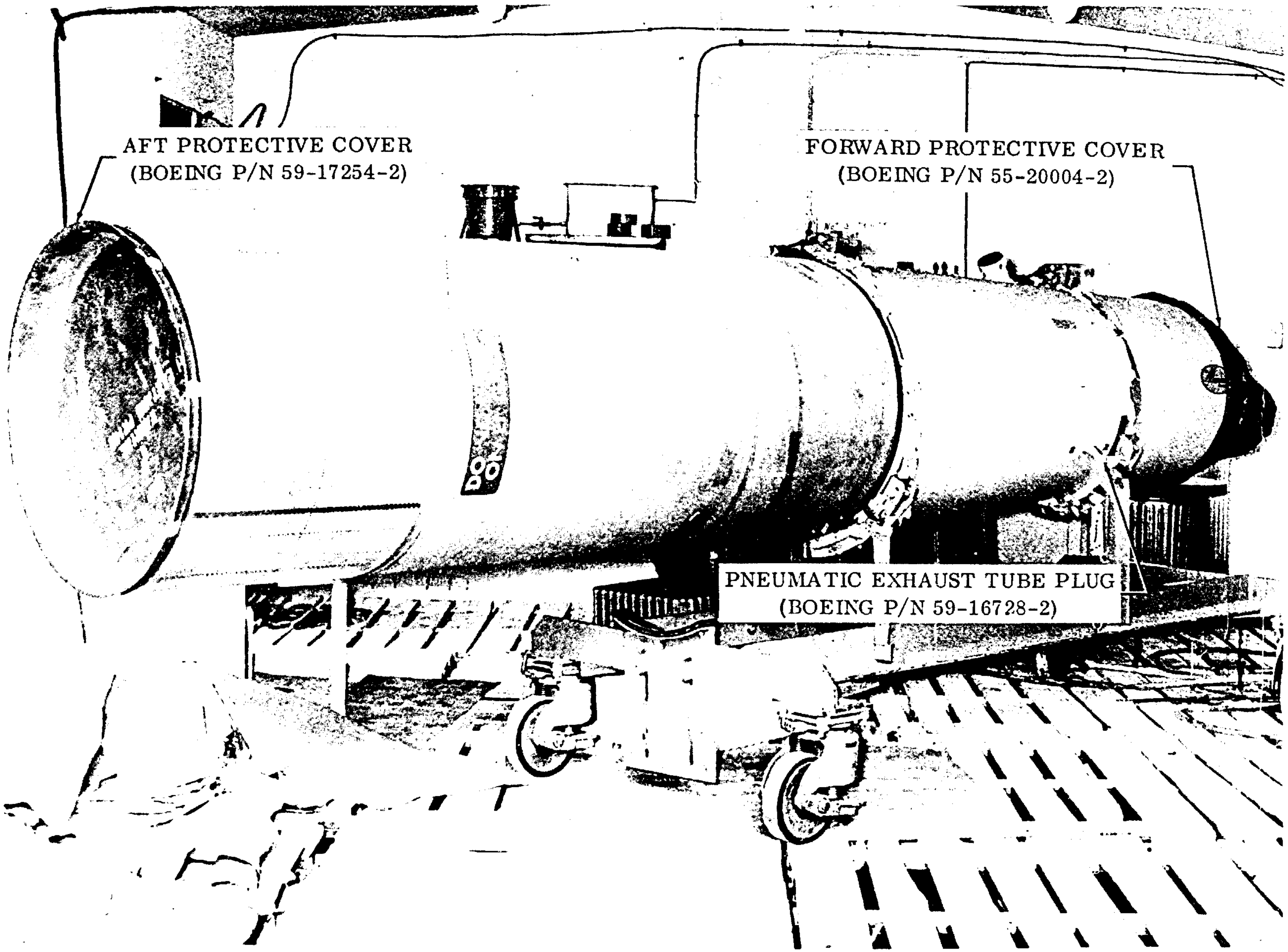

FIGURE 39 - Storage Site, From November 1962 to August 1963, For the RJ43-MA-11 Phase II Long-Term Storage Engine Serial MA-E10011-2. Area is Located at The Marquardt Corporation Main Plant in Ogden, Utah.

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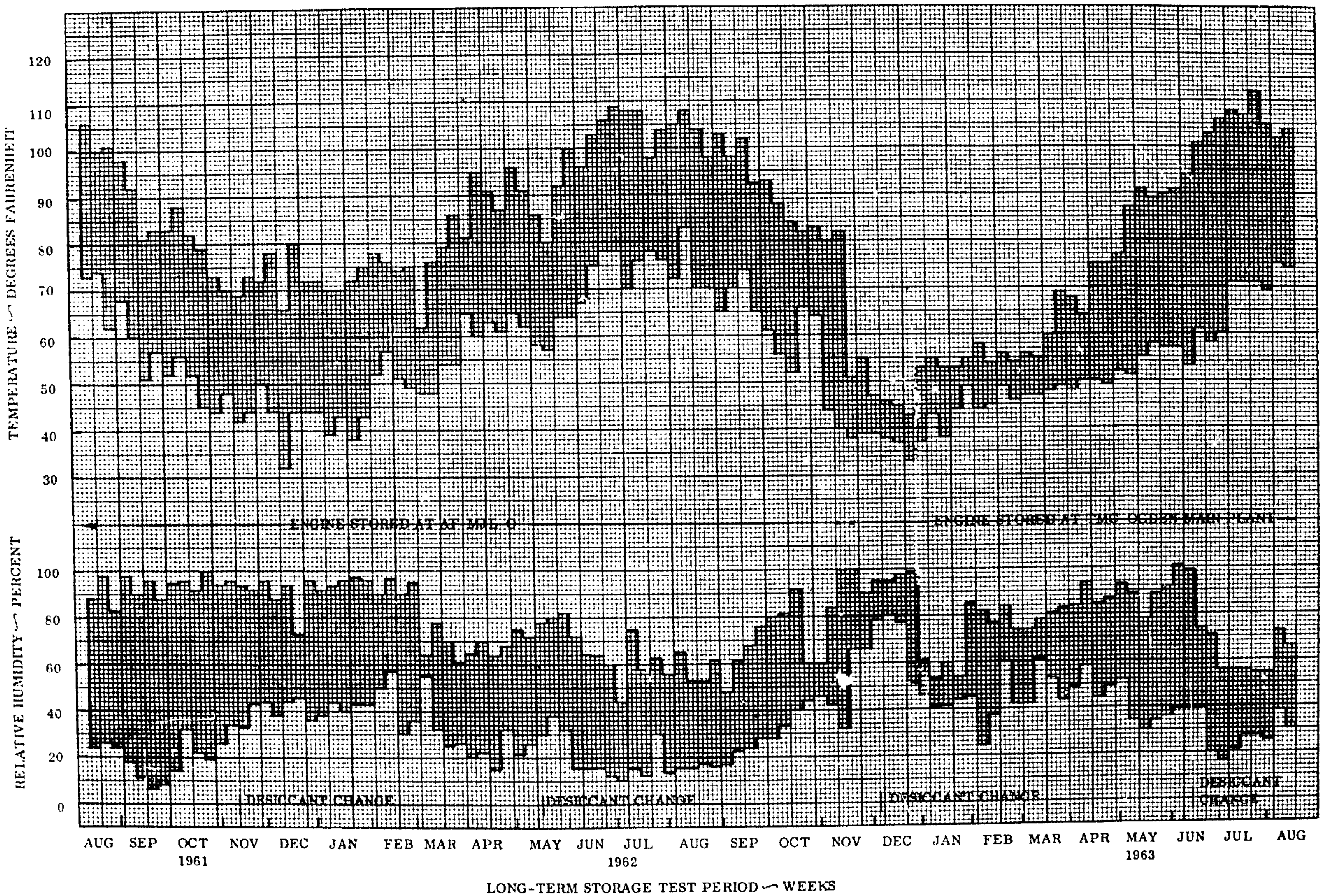
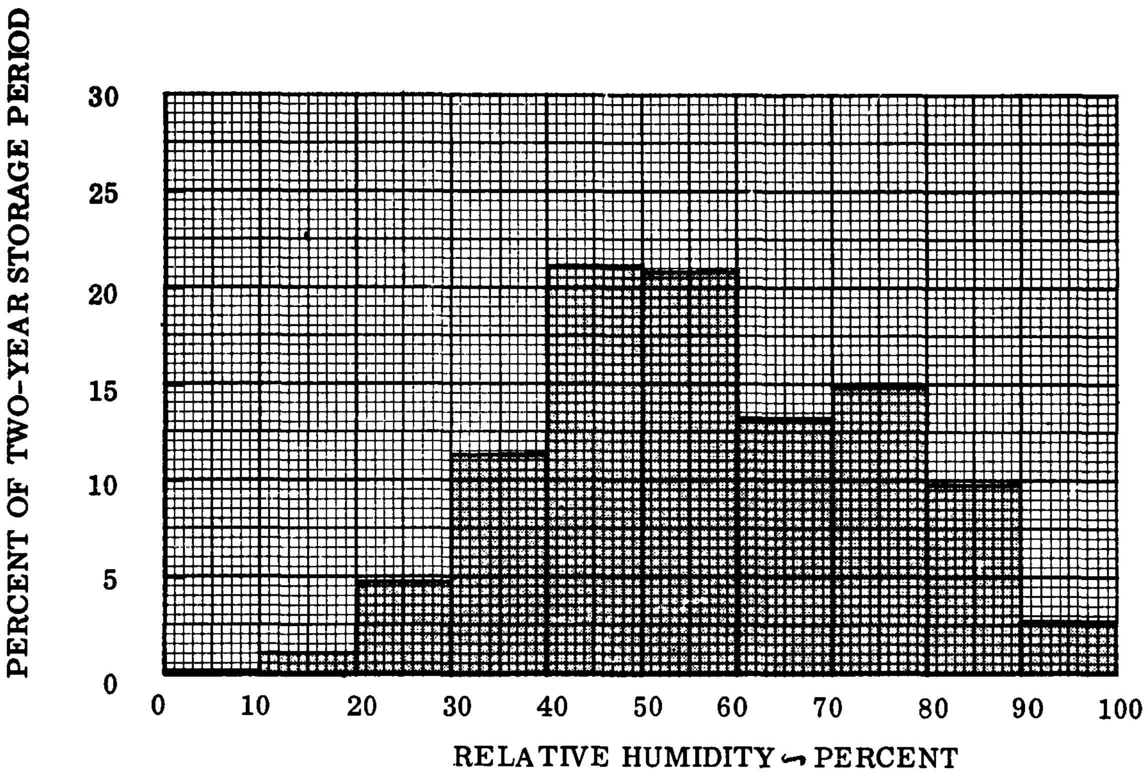


FIGURE 40 - Weekly High and Low Temperature and Relative Humidity Recorded in the Storage Enclosures During the RJ43-MA-11 Phase II Long-Term Storage Test.



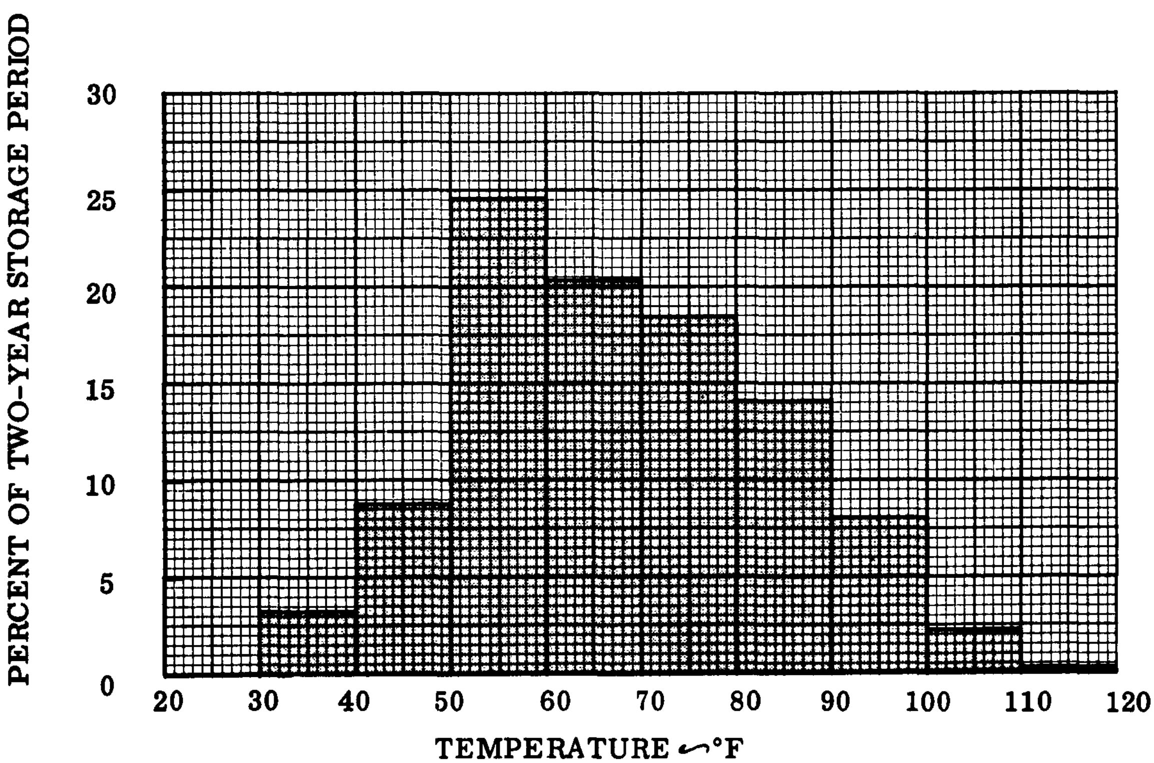


FIGURE 41 - Storage Enclosure Temperature and Relative Humidity Histograms for the RJ43-MA-11 Phase II Long-Term Storage Test.

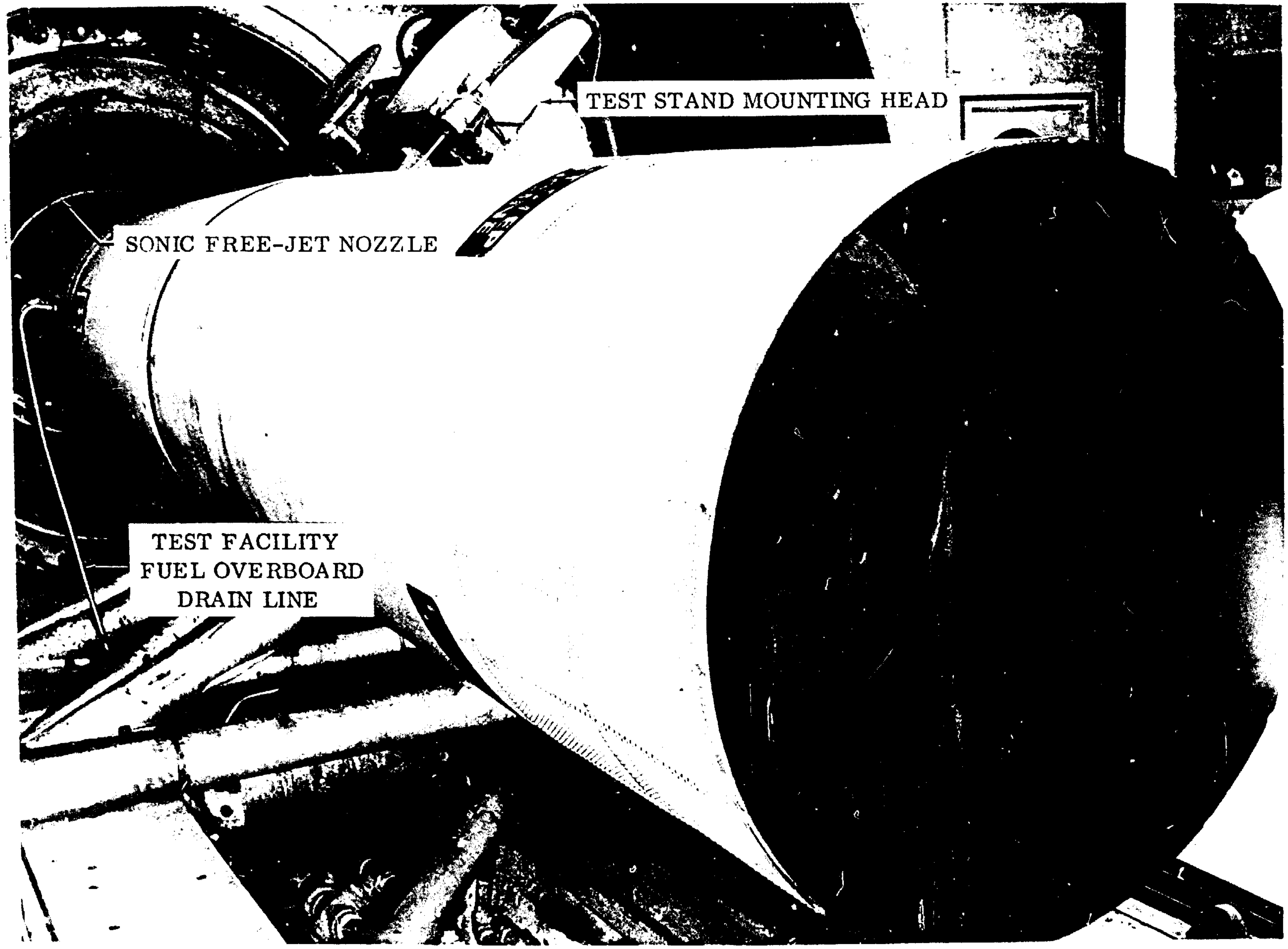


FIGURE 42 - RJ43-MA-11 Engine Serial MA-E10011-2 Installed in AF-MJL-VN Test Cell 3 for Ignition Demonstration Following Two-Year Period of Ready-Storage.

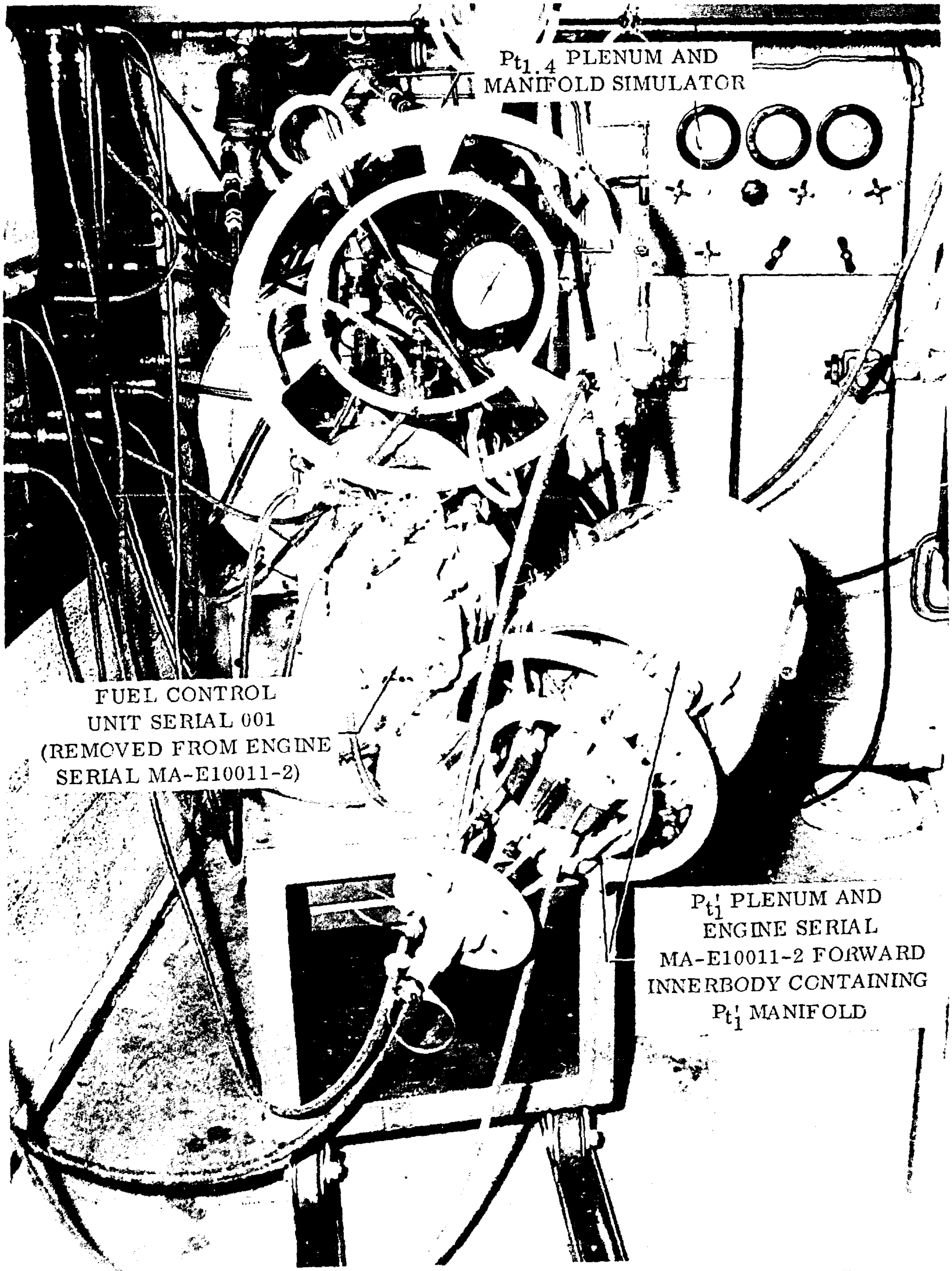


FIGURE 43 - RJ43-MA-11 Fuel Control Unit Serial 001 Installed in Test Jig For Calibration Test Following Two-Years of Ready-Storage.

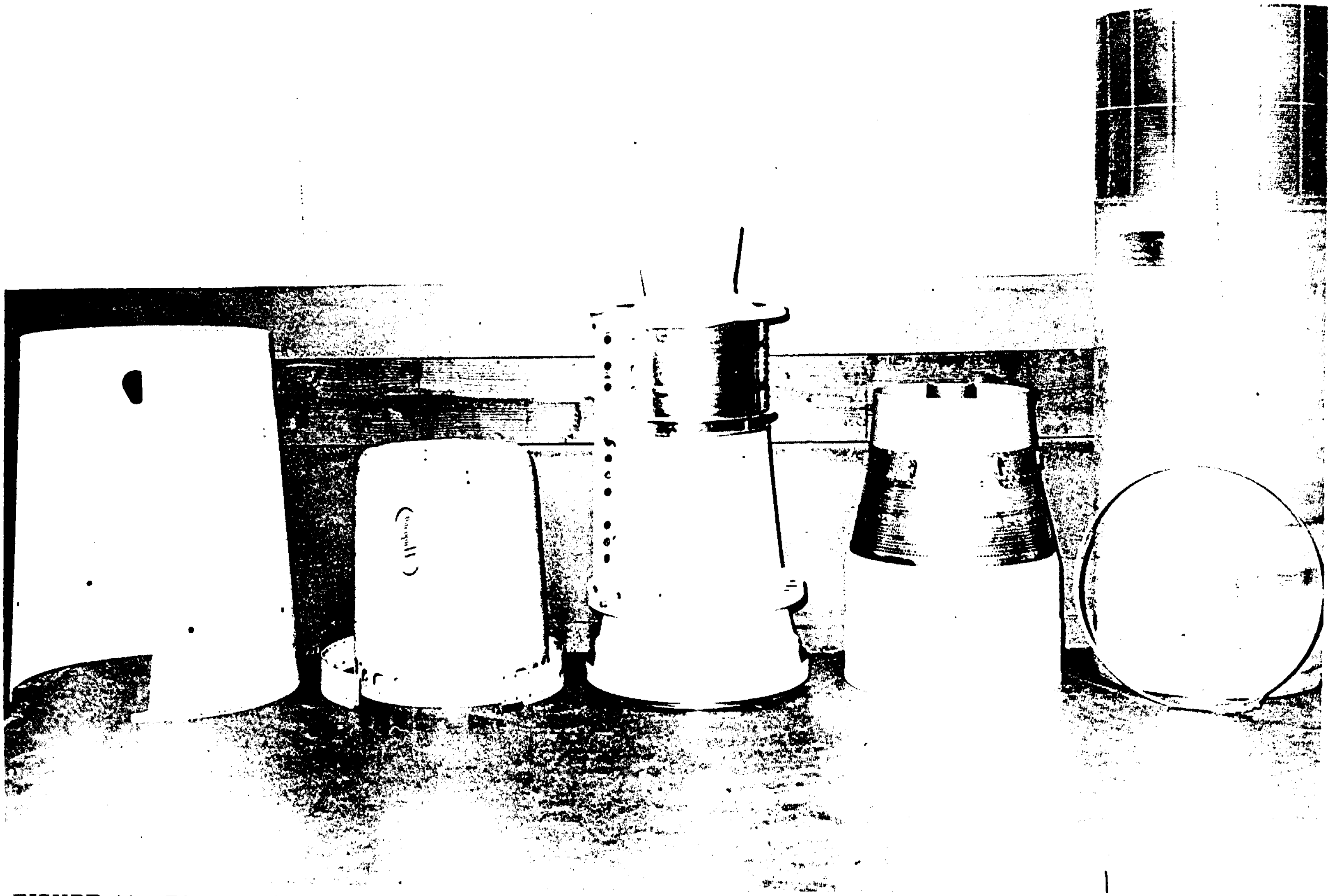


FIGURE 44 - Disassembled Components of RJ43-MA-11 Ramjet Engine Serial MA-E10011-2 Following the RJ43-MA-11 Phase II Long-Term Storage Test.

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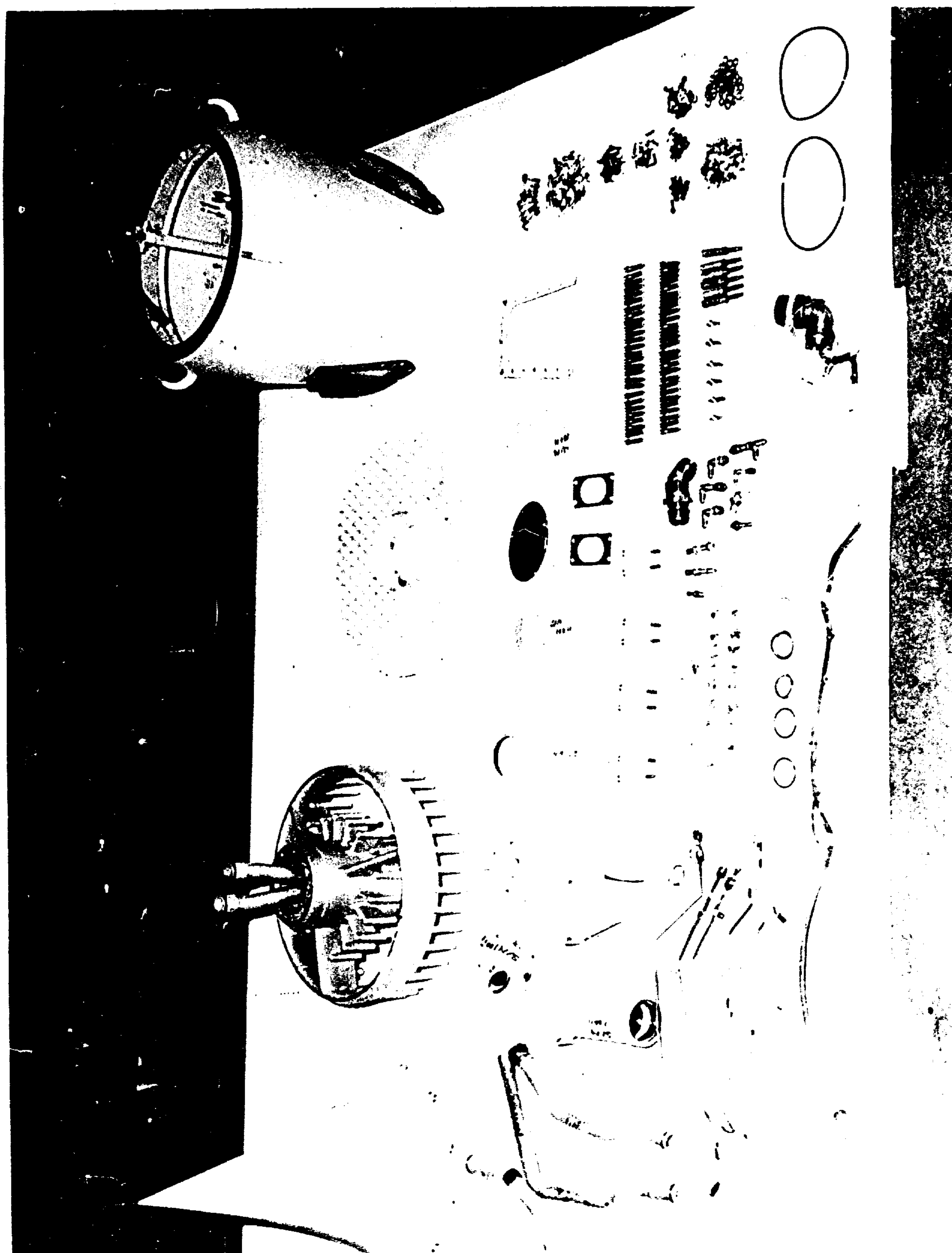

FIGURE 45 - Disassembled Components of RJ43-MA-11 Ramjet Engine Serial MA-E10011-2 Following the RJ43-MA-11 Phase II Long-Term Storage Test.

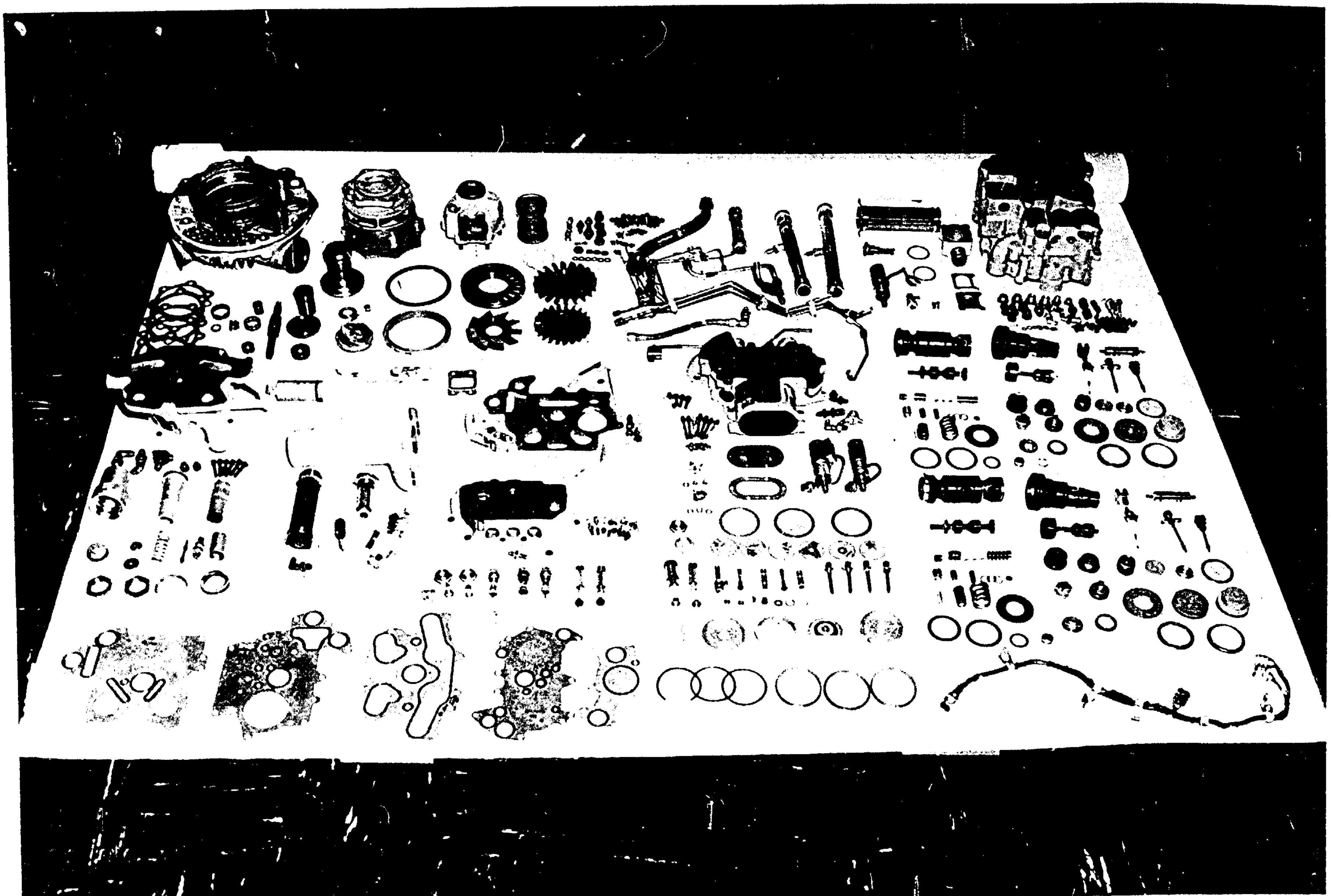

FIGURE 46 - Disassembled Components of RJ43-MA-11 Fuel Control Unit Serial 001, From Engine Serial MA-E10011-2, Following the RJ43-MA-11 Phase II Long-Term Storage Test.

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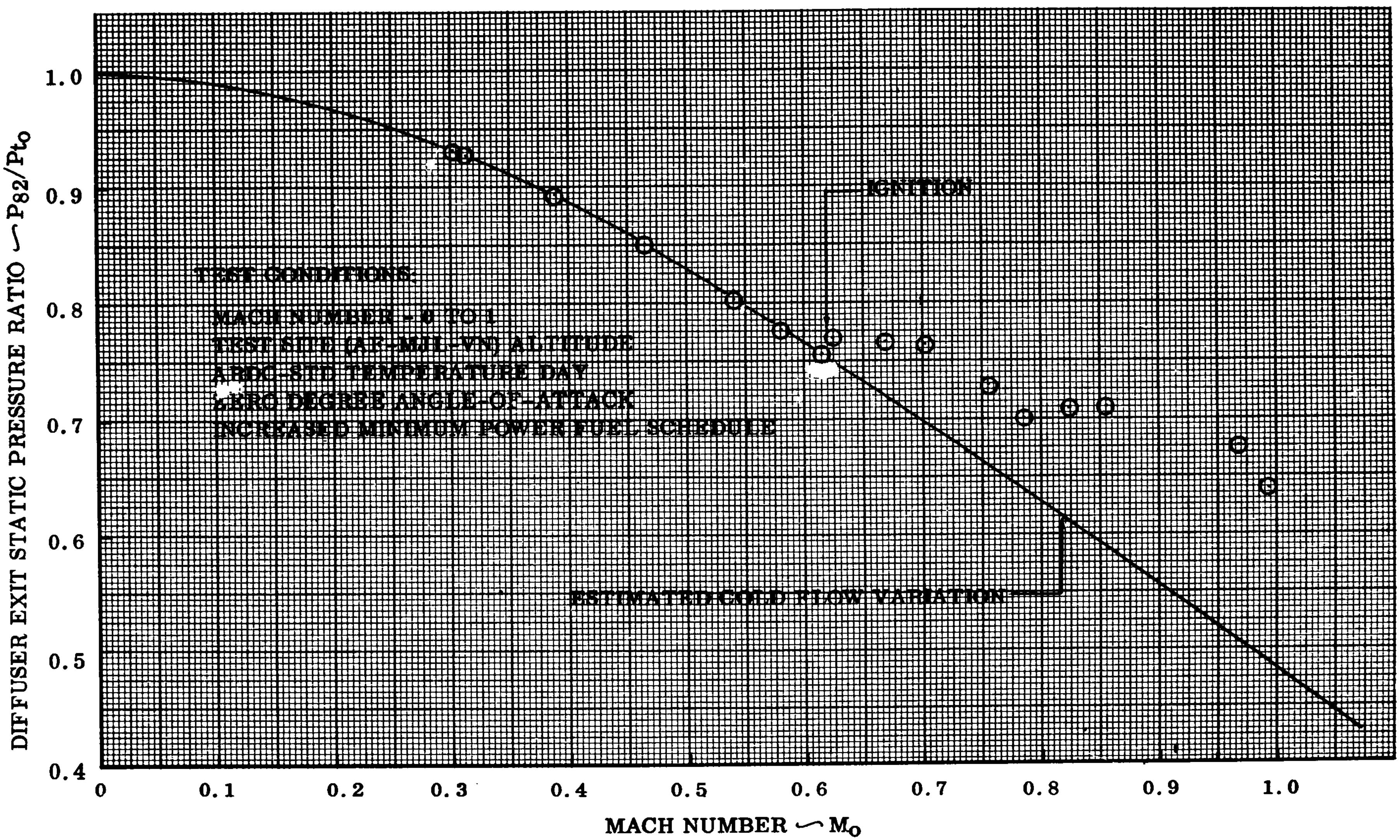

FIGURE 47 - RJ43-MA-11 Ramjet Engine Serial MA-E10011-2 Ignition Performance Following the RJ43-MA-11 Phase II Long-Term Storage Test.

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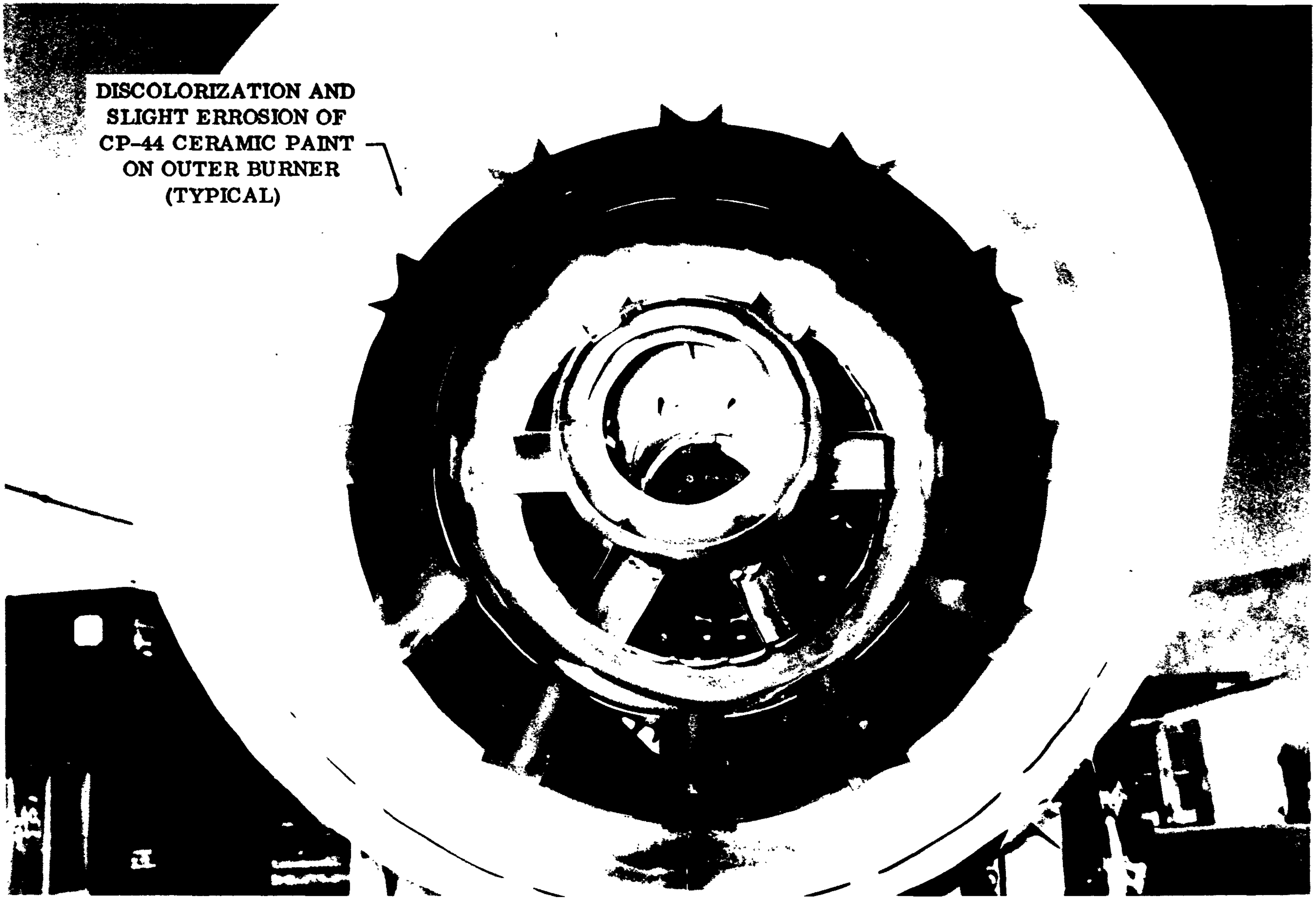

FIGURE 48 - View of Burner Assembly in RJ43-MA-11 Engine Serial MA-E10011-2 Following Ignition Demonstration Burn Run Showing Discolorization and Slight Erosion of CP-44 Coating.

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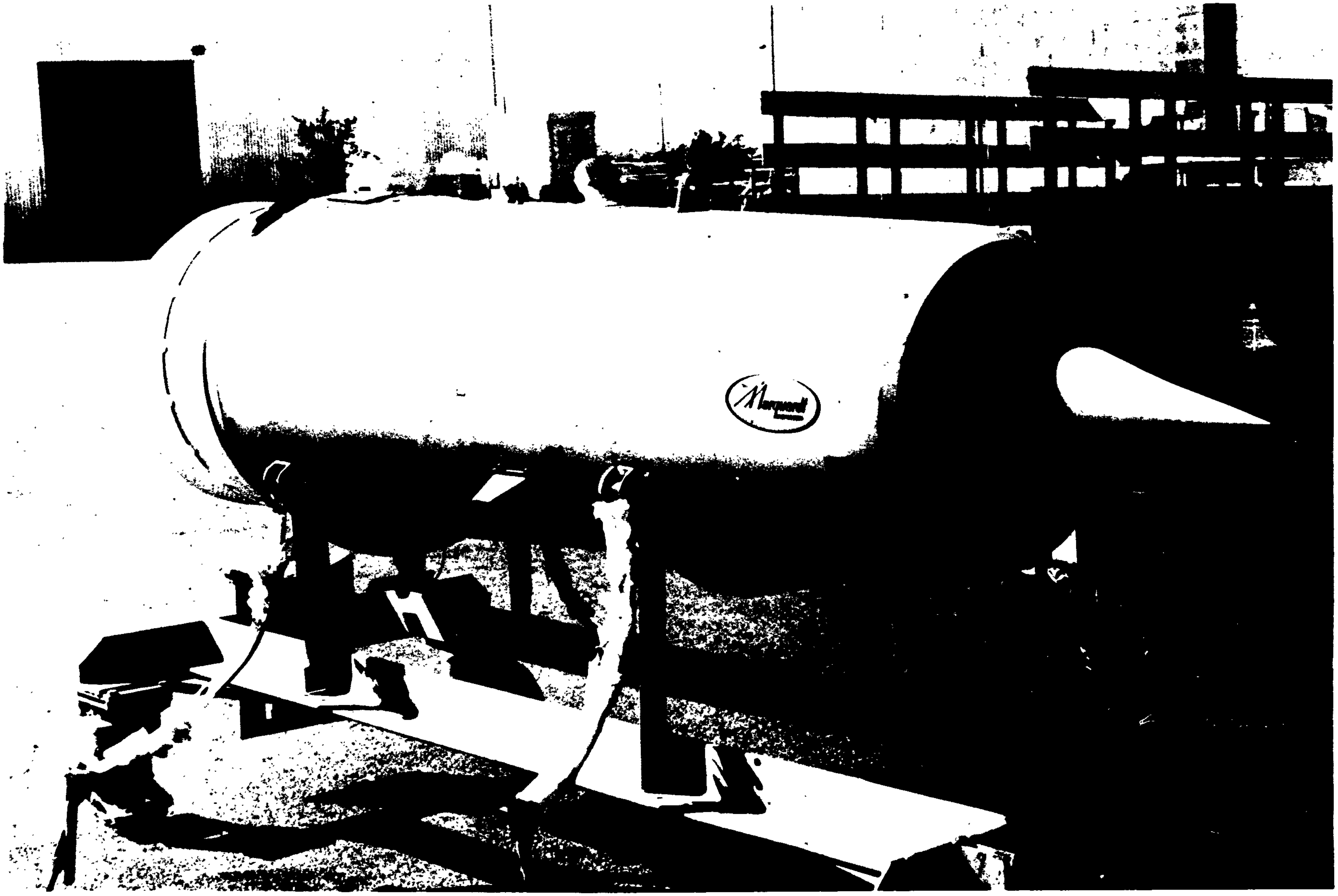

FIGURE 49 - RJ43-MA-11 Engine Serial MA-E10011-2 Main Structure Following Ignition Demonstration Burn Run Conducted After Two-Years of Ready-Storage.

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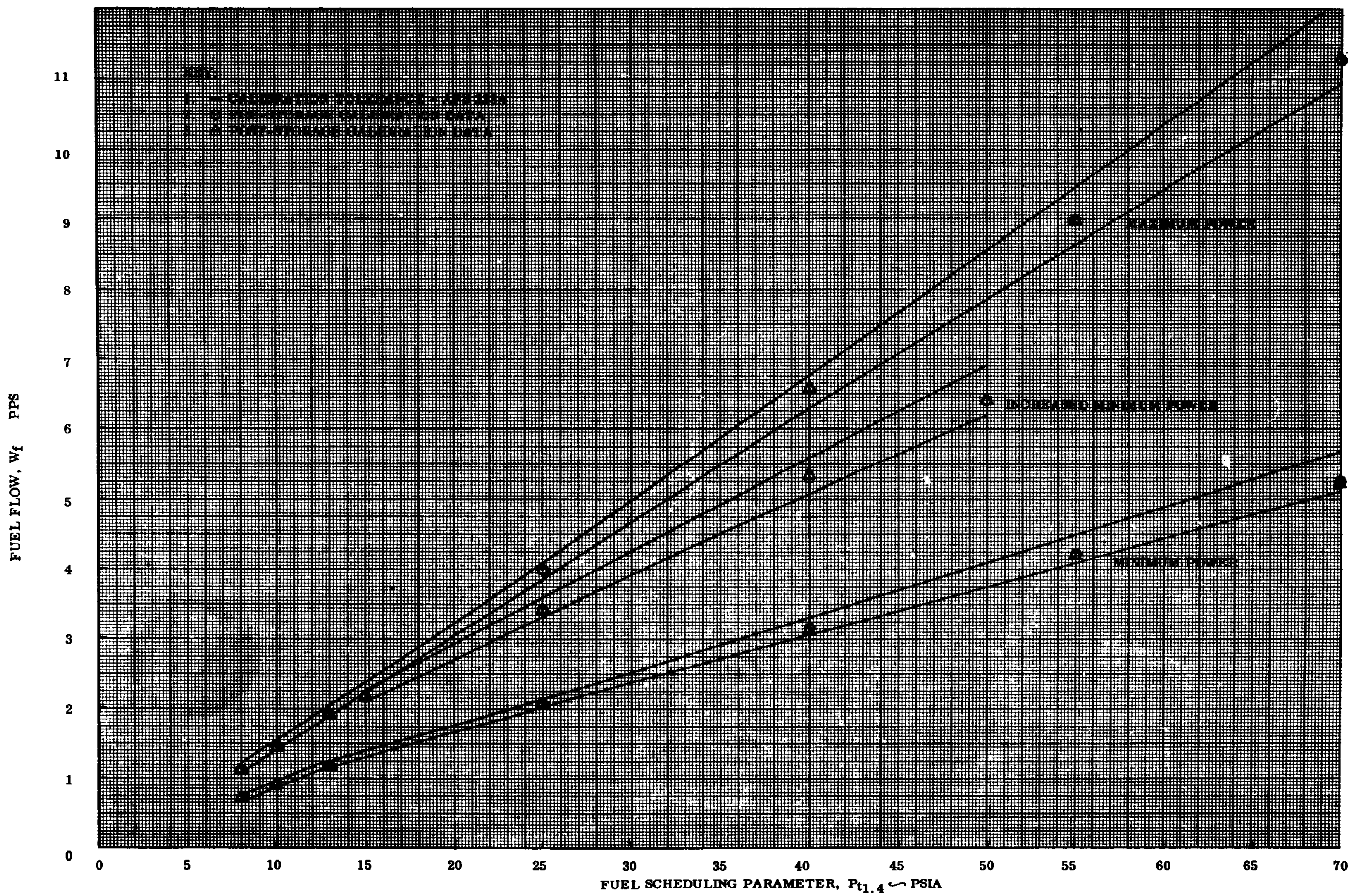

Before and After the RJ43-MA-11 Phase II Long-Term Storage Test.

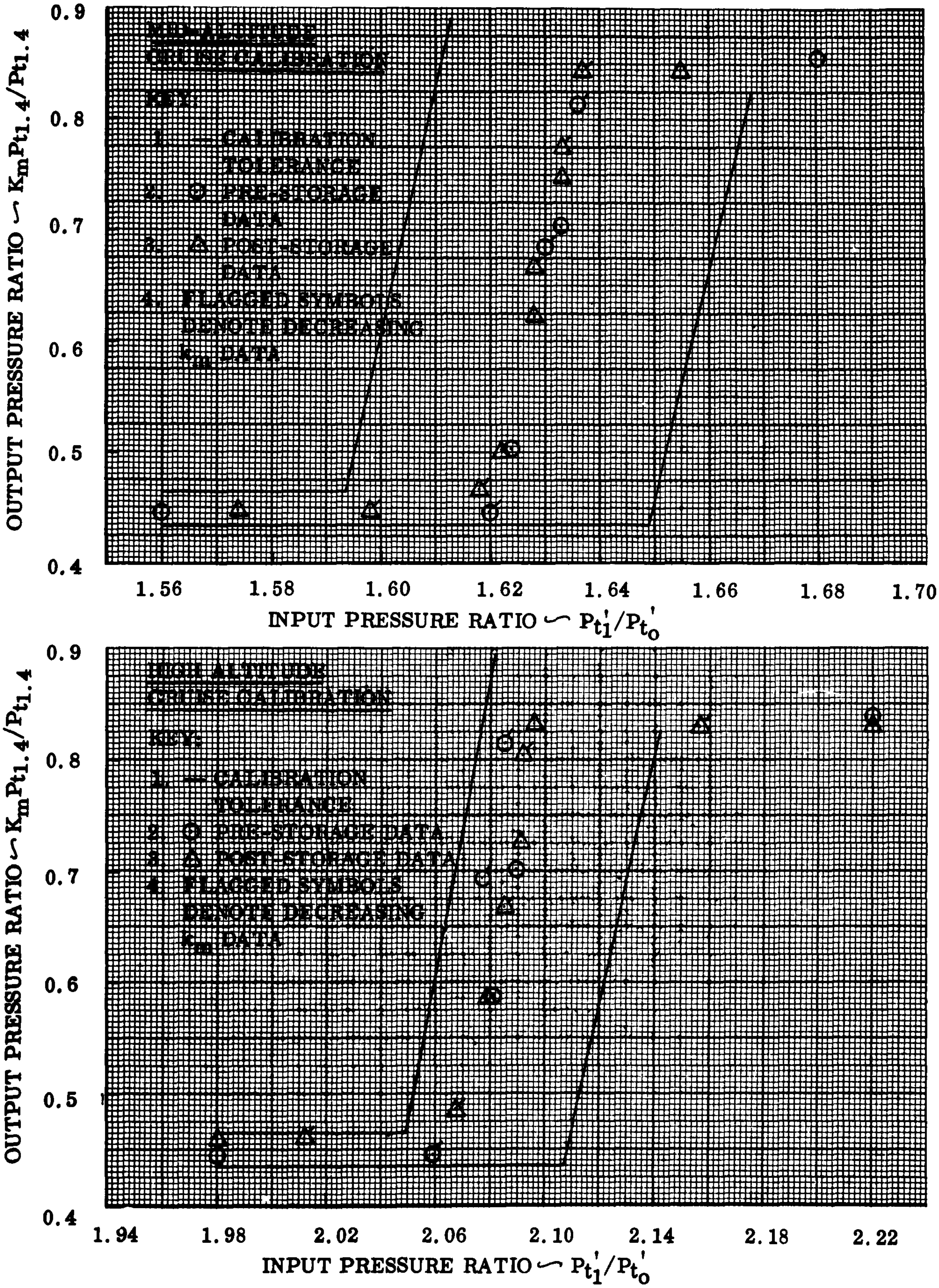

FIGURE 51 - RJ43-MA-11 Ramjet Engine Serial MA-E10011-2 Mach Senser Control Calibration Data Before and After the RJ43-MA-11 Phase II Long-Term Storage Test.

KEY:

1. — CALIBRATION TOLERANCE
2. ⊙ PRE-STORAGE DATA
3. △ POST-STORAGE DATA
4. FLAGGED SYMBOLS DENOTE DECREASING K_p DATA

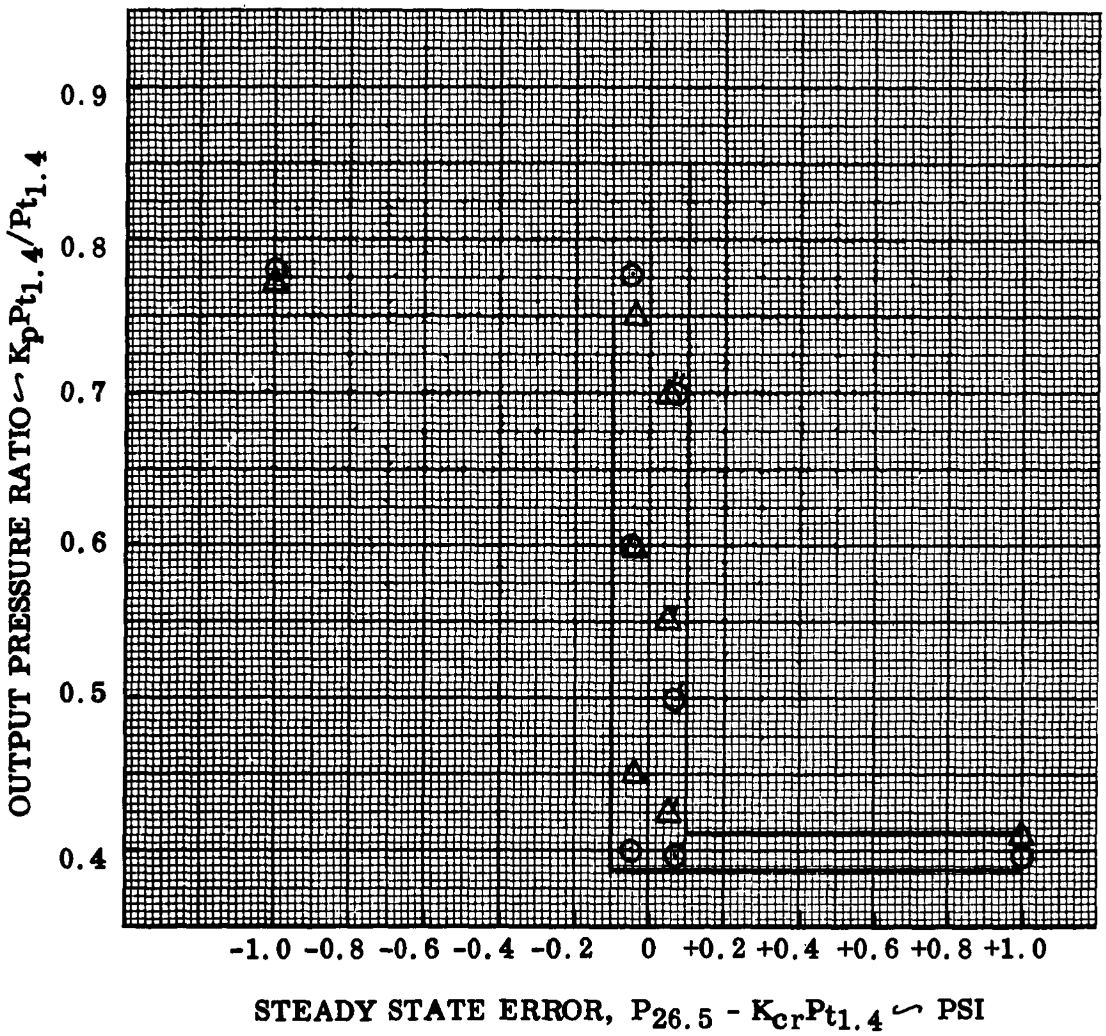

FIGURE 52 - RJ43-MA-11 Ramjet Engine Serial MA-E10011-2 Shock Position Control Calibration Data Before and After the RJ43-MA-11 Phase II Long-Term Storage Test.

VI CONCLUSIONS

The following conclusions are based on the results of the Phase II long-term storage test program and refer to RJ43-MA-11 engines stored under anticipated tactical environmental conditions in a state of flight readiness.

1. The life of the engine appears to be compatible with the design life of ten years.

2. A two-year interval for conduct of functional confidence checks is compatible with the design of the power control system.

3. No necessary changes in engine design, manufacturing processes, handling procedures or maintenance and servicing concepts to improve the engine storage capability are indicated for engines incorporating the design changes which resulted from the accelerated storage test.

THE Marquardt CORPORATION OGDEN, UTAH

VII REFERENCES

1. Marquardt Report 15081 (Title Unclassified), Results of the Phase I Long-Term Environmental Storage Test Program for the RJ43-MA-11 Ramjet Engine, October 1960 Through March 1963, dated 1 May 1963.

2. Marquardt Report 15036, Outline for the RJ43-MA-11 Ramjet Engine and Components Missile-Ready Environmental Storage Test Program, dated 24 August 1960.

3. Marquardt Test Specification 0191, Acceptance Test Specification for the RJ43-MA-11 Ramjet Engine, dated 15 October 1959, Revision H, dated 17 October 1960, Revision U, dated 5 June 1961.

4. Marquardt Report 15039, Environmental Testing of Three Selected RJ43-MA-11 Ramjet Engines and One Fuel Control Unit, dated 11 July 1960.

5. Military Specification MIL-E-5272C (ASG), Environmental Testing, Aeronautical and Associated Equipment, General Specification for, dated 13 April 1959.

6. Marquardt Process Specification 505, Priming and Painting of Metal Surfaces, dated 8 March 1951, revised 3 April 1961.

7. Marquardt Specification 5602E (Title Unclassified), Model Specification for the RJ43-MA-11 Ramjet Engine (Marquardt Model MA20ZS-3), dated 21 September 1956, revised 1 April 1961.

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